BLACKIE'S SCIENCE READERS
No. V.

THE YOUNG CHEMISTS

BY

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"OUTDOOR WORLD", "BRITISH BUTTERFLIES AND MOTHS", ETC.

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PREFACE.

The series of readers of which this forms a volume is especially *adapted for use in schools in which Elementary Science is taught* as a class subject. But, while the scientific facts are accurately presented, the volumes do not pretend to be *manuals* of science. They are distinctively *reading-books*, and the narrative form in which they are cast, together with the native attractiveness of the subjects treated, gives them a sustained interest which fits them for use as general readers in schools where science is not specifically taught.

The subjects selected are those named or suggested in the Schedules of the Education Code, and the reading lessons will prove useful either as introductions to or as adjuncts of the more systematic oral lessons of the teacher.

Each book is illustrated with pictures belonging both to the narrative and the subject-matter, and concludes with a succinct synopsis of the scientific material of the lessons, and explanations of the more difficult words in the text.

The present volume contains simple and informal lessons in Chemistry.

CONTENTS.

Part I.—INTRODUCTORY.

Part II.—COMMON INORGANIC SUBSTANCES.

Part III.—COMMON METALS.

Part IV.—ORGANIC CHEMISTRY.

THE YOUNG CHEMISTS.

Part I.—INTRODUCTORY.

1. WHAT IS CHEMISTRY?

"Oh, look here!" exclaimed Tom to his companions; "that's a queer subject for a lecture—isn't it?"

Tom's eye had just caught sight of a bill announcing a lecture that was to be given a few days later on "A Rusty Nail".

His mates all crowded round the strange notice, and began to wonder what the lecturer could find to say about such a thing as an old rusty nail.

Just then Tom's father, who was accompanying the boys in their ramble, joined the little group, and was much amused at their remarks on the unknown lecturer and his peculiar subject.

"I should call that a most interesting and useful subject," said he. "It is really a lecture on chemistry; and, you see by the bill, that it is to be illustrated by a number of experiments."

"But what is chemistry?" asked Bob—the smallest boy of the group, and one who would never remain ignorant on any matter if he could get the information he wanted by asking.

"Chemistry", said Mr. Wood (for that was the name of Tom's father), "teaches us what substances are composed of. For instance, it teaches us that water is formed of two gases, which are quite

invisible when apart; and that salt may be broken up into a greenish-yellow gas and a silver-white metal.

"Chemists have done a splendid work for the world. They have enabled us to understand many of the wonderful changes that are continually taking

place around us. They have found out how to cause substances to combine and form other useful substances that we should not have had without their labour. They have taught us how to get valuable metals and other materials from substances that were once of no use to us."

"I think we should all like to know something of this subject," said Tom. "Couldn't you take us to hear this lecture about the rusty nail?"

"Well, you see by this bill that the lecture is to be given in the next town, and the distance makes it rather inconvenient for us; but I will do what I think will suit you all just as well. If you will come round to my house for an hour every Friday evening, I will give you some lessons on chemistry similar to those which I heard when I was at College."

But Harold, who liked fun better than work, and who was very anxious to see if he couldn't get some amusement out of the lecturer's "brilliant experiments", thought it would be better to go to the lecture than to sit down in Mr. Wood's study and only *hear* about chemistry.

"I should like to see the experiments," he said. "That must be the best part of the fun."

Mr. Wood, however, made all their eyes flash with delight when he told them that *he* had a large quantity of chemicals and apparatus, and that *he* would perform experiments to illustrate every lesson he gave them.

"Oh, that is jolly!" said Harold. "When shall we have our first lesson?"

"We will start next Friday," said Mr. Wood. "Come over to my house at six. Tom and I will get everything ready before you arrive."

I need hardly tell you that the boys were all highly pleased with the outlook, and during the remainder of their ramble, which was now nearly at an end, they talked of nothing but the new subject they were to study.

I have already mentioned three of the boys—Tom, Bob, and Harold. There were also two others. One of them was Arthur—a very quiet lad, but very thoughtful.

The other was called Harry. He was very fond of his books. He had already *read* a great deal about chemistry and other sciences, but he had *seen* very few of the things he had read about.

2. ELEMENTS AND COMPOUNDS.

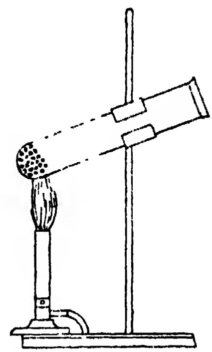
On the following Friday the boys were all at Mr. Wood's house in good time, and they found that Tom and his father had made preparations for their first lesson.

"Now, boys," Mr. Wood began, "you remember I told you that chemists have found out what substances are composed of. I am going, this

evening, to give you an illustration of that part of their work."

"I wish you would show us what that silvery stuff is composed of," said Bob, who had been much attracted by the sight of a bottle of bright liquid metal.

"I can't do that, my boy," said Mr. Wood. "That substance is mercury or quicksilver, and is one of those forms of matter called *elements*, which cannot be broken up into simpler substances. Out of quicksilver only quicksilver can be obtained. We don't know what may be done with it in the future, when the science of chemistry is more advanced, but for the present we must look upon it as an element."



Heating Mercury Oxide in a Test-tube.

"Is water an element too?" asked Bob.

"No," replied Mr. Wood. "I have already told you that water can be broken up into two gases All those substances which can be thus reduced to simpler forms are called *compounds*.

"Look at this red powder. It is called mercury oxide or red oxide of mercury. I will put a little of it in this test-tube, and heat it in the gas flame.

"Now you see something settling on the side of the tube in the form of little shining drops. That

is the liquid metal called quicksilver or mercury."

"Can you get it out so that we may handle it?" asked Bob.

"Yes, but before I do so, I will put this thin chip of wood, with a spark on the end of it, into the tube." He did this, and presently the chip blazed up brightly. "See," continued Mr. Wood, "the spark has burst into a small but bright flame."

He continued to heat the tube till at last there was nothing at all left at the bottom where the red powder had been. Then he asked the boys where it had all gone.

Harry was the only one who seemed to understand the experiment. "The substance was a compound," he said, "but has been split up into its elements—mercury and oxygen."

"That is right," said Mr. Wood; "the mercury came away in the form of a vapour, and settled down on the tube, forming little drops of the liquid metal. And it was the oxygen that caused the spark to burst into a flame."

"So you see," he continued, "I have proved to you that mercury oxide is a compound, for I have broken it up into two substances. Chemists would say that I had *analysed* the mercury oxide."

"But", said Arthur, "you have not proved that the mercury and the oxygen are elements."

"No," answered Mr. Wood, "I have certainly

not done that, but I can tell you that nobody has yet been able to break up either of these substances, and therefore we regard them as elements."

"Does heat always break up compounds into their elements?" asked Bob.

"No; sometimes it causes elements to combine and form compounds, as I shall show you on a future occasion."

Harold now took up two bottles, one containing mercury and the other mercury oxide, and after examining them seemed very much puzzled.

Mr. Wood asked him what he was thinking about.

"I have been trying to see the mercury in this bottle of red powder," he said. "It doesn't look at all like mercury. It is a bright-red powder, and mercury is just like melted silver."

"Very true," said Mr. Wood, "but when a compound substance is split up into its elements, it is found that these are generally very different from the compound. You remember that last time I told you that water breaks up into two invisible gases, and common salt breaks up into a greenish-yellow gas and a silver-white metal."

"How many elements are there?" inquired Tom.

"About seventy are now known to chemists,[1] but it is probable that there are many more still to be discovered.

"Quite a large proportion of the known elements are very rare, and you may have never heard even the names of some of them.

"Others are very abundant, but so difficult to prepare from their compounds that they are seldom seen except by chemists."

Mr. Wood now sent the boys home, telling them that he should have more to say about elements when next they visited him.

[1] A list of the more important elements will be found on page 196.

3. BUILDING UP COMPOUNDS.

When next the boys met at Mr. Wood's house, he briefly reminded them of what he had told them on the last occasion.

"I showed you," he said, "how to split up mercury oxide into its two elements. But it is possible also to take the elements, and form the compound from them.

"If quicksilver is exposed to the air without being heated, no chemical change takes place; but if the metal is heated up to a certain temperature, and kept at that temperature for a very long time, it will slowly combine with oxygen of the air, forming mercury oxide.

"I will give you some more illustrations of building up compounds," he continued.

"Look at this piece of wire. Can you tell me what it is made of?"

"It looks like silver," said Tom.

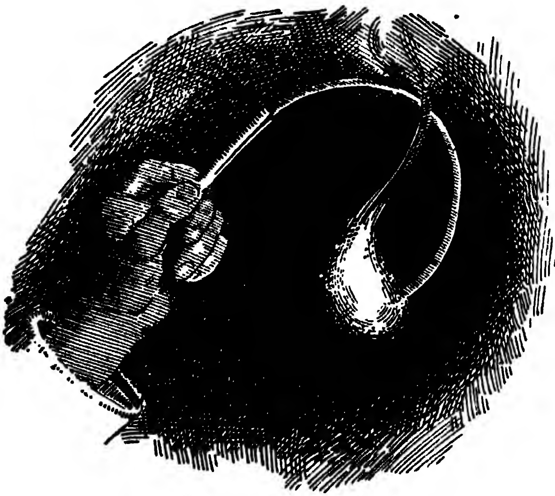
"Yes, it *looks* like silver," said Mr. Wood, "but there are several metals with a silvery appearance. This one is called magnesium. I will heat it in the gas flame, and you must observe what takes place."

Mr. Wood then took up the ribbon with a small pair of tongs, and put the end of it in the gas flame.

In a few seconds it began to burn with a very

brilliant white light, which dazzled their eyes. Then, when the combustion was over, a white substance dropped on the table, and broke into several pieces.

"Magnesium", said Mr. Wood, "is an element.



Magnesium Wire Burning.

When it is made very hot, it combines with oxygen of the air, and forms the white chalky compound which you see on the table, and which is called *magnesium oxide.*"

The boys then examined the white substance, and observed that it was not at all like the metal from which it had been formed. The metal was hard, like silver, but the oxide was so soft that,

when rubbed very gently with the tip of the finger, it was reduced to a very fine powder.

"Now look at these two iron nails, boys. One of them has a very bright surface, and the other is covered with a reddish substance, which we call rust.

"A few days ago both the nails were bright, but I kept one in a drawer in this room, and put the other on the ledge outside the window.

"The one that was kept indoors, where the air is dry, has not changed at all; but the other one, which has been exposed to the moist air outside, has combined with oxygen, forming a compound which is called iron rust or iron oxide.

"If the nail were allowed to remain out of doors for a very long time, the whole of it would at last become rust."

"My father has some iron arches in the garden," said Bob, "but they do not rust, because he paints them."

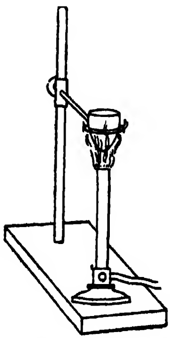
"Yes, that is one way of preventing iron from combining with oxygen," replied Mr. Wood. "A coating of grease will also prevent the atmosphere from acting on the metal.

"Now I will show you that iron may be made to combine with oxygen rapidly.

"Here is some pure iron in the form of a very fine powder. I will put a little into this crucible, and heat it over the gas-flame."

The boys were now allowed to look into the crucible to see what took place.

In a very short time they saw the metal glow, and then go dull again.



Iron heated in a Crucible.

"The change is over now, boys. The iron has combined with oxygen of the air, and has all been converted into iron oxide."

"I thought the reddish rust that formed on the surface of the iron nail was iron oxide," said Tom, "but it is not much like the oxide in the crucible."

"That is quite true," replied Mr. Wood. "Both these compounds are iron oxides, but they are not of exactly the same composition."

"Ordinary rust is the *red oxide* of iron. But when iron is made red-hot, and is at the same time exposed to air, it always forms a *black oxide.*

"The same oxide is formed when a piece of iron is made red-hot in a fire or any very hot flame. If you put a bright iron poker in the fire till it is red-hot, you will find, when it has cooled, that it is covered with a thin layer of the black oxide.

"As you go homeward this evening, ask Mr. James, the blacksmith, to let you have a look at his workshop, and you will find the floor covered

with scales of this same black oxide, which have been knocked off the iron by his hammer.

"And if he is at work at the forge, you will also be able to see pieces of oxide flying from the iron as it is hammered. Of course they are red-hot as they fly through the air, but they soon cool down, and are then just like the substance that covers the floor of the shop."

4. METALS AND NON-METALS.

When the boys arrived for their next lesson they saw two or three dozen bottles on Mr. Wood's table.

Some of them appeared to be quite empty, but the others contained a number of different substances. They were also arranged in two rows, in one of which they recognized mercury, iron, magnesium, and a few other substances.

"These bottles", said Mr. Wood, "each contain an elementary substance."

"But four of the bottles are empty," said Harold.

"No, they are not empty. There is an elementary substance in every one," replied Mr. Wood.

"Well, I can't *see* anything of them," replied Harold.

"Very likely, but four of the elements are usually in the form of gases."

"Oh, I understand! but how did you get the gases into the bottles?"

"That was a very easy matter, but I shall not be able to show you now how to prepare and bottle the gases, though some day I shall do so."

"You show us a number of elements, Mr. Wood," said Harold, "but you cannot show us the gases, for they are invisible. I see you have put one of them into a yellow bottle. Why have you done that?"

"Ah, Harold, you're caught again! The bottle isn't yellow, but the gas it contains is of a greenish-yellow colour."

"What! a yellow gas?" cried Bob.

"Yes, certainly," said Mr. Wood. There are a number of coloured gases; only they are not commonly known except to chemists. This one is called *chlorine.*"

"What are the other three gases?" said Arthur, "and how can you tell one from the other, since they are all invisible?"

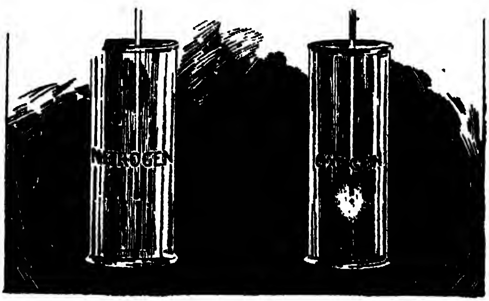
"This first one is *hydrogen.* It is the lightest of all the elements. When I remove the stopper of the bottle, and apply a light to its mouth, you see the gas burns with a pale-blue flame.

"The next bottle contains *oxygen.* When I put this glowing match into the gas, the match bursts into a brilliant flame, but the gas itself does not burn.

"The next bottle contains *nitrogen* gas. When I plunge a lighted taper into it, you see that the

taper is immediately extinguished, and the gas does not burn.

"Now," continued Mr. Wood, "look at the other substances in the same row with the bottles of gas. Here is a black substance called *carbon*, a yellow one called *sulphur*, a bluish-black one called *iodine*,



The Effects of Oxygen and Nitrogen on a Lighted Match.

another yellow one called *phosphorus*, and a dark-brown liquid called *bromine.* Bromine is the only liquid non-metal. These are all elementary substances, and all of them are called non-metals."

"When you were speaking of hydrogen, chlorine, oxygen, and nitrogen," said Tom, "you said they were usually in the form of gases. What do you mean by that?"

"I mean this. There are three different states in which substances may exist—the solid, liquid, and gaseous states. Some of them can be easily changed from one state to another. The particular

state in which they usually exist depends on the amount of heat they contain.

"Sulphur, for instance, is usually solid, but by heating it you can change it into a liquid, or with still more heat, into a gas.

"Mercury, on the other hand, is generally in the liquid state, but may be frozen or turned into the solid state by means of very great cold.

"Then, again, there are other substances, such as chlorine, that boil with so little heat that they usually exist as gases; but we can convert them into the liquid, or even the solid state, by causing them to become extremely cold."

"Oh, I see now! Do you think you will be able to show us some of these changes?"

"Yes, but not to-day. In our future lessons you will be able to observe several such changes. But we have spent so much time in talking about the non-metals, that we shall have to put aside the others—the metals—till next week."

5. METALS AND NON-METALS (*Continued*).

When they met on the following Friday the boys saw the same array of bottles on the table, but they were not displeased, for they knew that Mr. Wood was going to give them further interesting information about the elements.

"Now," he began, "look at this long row of bottles containing metals, and see if any of you can *tell me in what respects they are all alike.*"

"I know one," said Bob; "they are all bright."

"Not quite all," interrupted Harold. "I see a dull one."

"That one is the metal sodium," said their instructor. "But let me take it out of the bottle and show it to you."

"You see it *is* dull, but I will cut it with my knife. There, it now shines just like silver, but see how soon it goes dull again.

"All the metals have bright surfaces when pure, but some of them, like this sodium, soon tarnish when exposed to air.

"Now, who can tell me another respect in which metals are all alike?"

Then meddlesome and inquisitive Bob, who had been taking up some of the bottles, said they were all very heavy.

"Many of the metals are certainly heavy, but not all of them. Try this piece of sodium, Bob."

Mr. Wood then put a rather large piece of sodium in Bob's hand, and Bob was obliged to admit that one metal at least was very light.

"It is a common mistake to suppose that all metals are heavy because the well-known ones are; sodium and some others are so light that they float on water." said Mr. Wood.

He then pointed out that, although all the metals had bright surfaces, yet they were of different colours, some being grayish, some bluish, and one (copper) of a red colour.

"Now," said he, "I will tell you of a property belonging to all metals—a property which you cannot tell by simply looking at them.

"Take this piece of copper wire, Harold, and hold the end of it in the gas flame till I tell you to take it out."

That just suited Harold. He was very fond of experiments, and was pleased to be allowed to perform one himself.

The copper had not been in the flame long before Tom exclaimed: "Oh, what a pretty bluish-green light!"

"Yes, that is one of the things by which we may know copper, but keep it in the flame, Harold, and we may observe something more presently."

And so they did, for the next moment Harold gave a sudden cry, threw down the piece of copper, and began to shake his hand violently.

"What's the matter, Harold?" cried two or three of them together.

"Matter enough," said Harold, pulling a long face, and looking at his thumb to see if he could find a blister, while all the others seemed to treat the matter as a joke.

"Why did you take hold of the hot end?" said Tom.

"I didn't," said Harold, who could laugh himself now, for the pain had all gone. "The heat came through the copper and burnt my fingers."

"That is just what I want you to know," said Mr. Wood. "*All* the metals are good conductors of heat; that is, they allow heat to pass readily through them."

"There is another property by which we may know the metals. Here is a piece of tin, and when I hold it in the gas flame you see it soon melts and drops down on the table."

"But the copper didn't melt," said Harry.

"No, the copper did not melt, simply because the flame was not hot enough; but all metals can be melted, though a very great heat is required for some of them."

"Can you dissolve metals in water or any other liquid?" asked Arthur.

"Yes, some of them can be dissolved in water, and the others in acids, or mixtures of acids; but there is this peculiarity about them. Whenever they are dissolved, they always combine with one or more of the elements of the liquid into which you have placed them, so that they are really changed into new substances."

6. MIXTURES AND COMPOUNDS.

"Now, boys," said Mr. Wood, on the next occasion of meeting, "I am going to show you the difference between *simple mixtures* and *chemical compounds.*"

"Tom, you weigh forty grains of flowers of sulphur in these little scales, and afterwards seventy grains of fine iron filings."

This was soon done, and the two pieces of paper on which the substances had been laid were passed over to Bob with a request to mix them thoroughly together.

"Now I want you all to look closely into this little heap, and tell me whether the two substances have combined together to form a compound."

"I think they have," said Harold.

"Well, tell me what reason you have for thinking so."

"You told us some time ago," replied Harold, "that when two or more elements combine, they form a compound that is very different in appearance and properties; and the yellow sulphur and black iron filings have formed a greenish substance."

"A very good answer, Harold, even though it is not a correct one."

Tom laughed heartily at this remark, and said: "How can it be a good answer if it is wrong?"

"It is a good answer because it shows that

Harold remembers what he is taught. There is certainly a change in appearance; but yet if Harold had looked very closely into the mixture, he might have seen that the iron and the sulphur have not changed in the least."

"Take this magnifying-glass, Harold, and look again."

Harold did so, and exclaimed: "Oh, now I can see little pieces of iron and little pieces of sulphur. They are not really changed, but are only mixed together."

"Now I will give you another proof that the iron and the sulphur have not combined. I will apply a magnet to the little heap. There, you see that a great deal of the iron has been attracted out. Much of the sulphur also comes up with the iron, looking like a yellow dust on its surface, but most of that is easily shaken off, and a puff or two of air from my mouth will blow off the rest."

"Is it possible to make the iron and sulphur really combine?" asked Harry.

"Yes, that is just what I am about to do."

Saying this, Mr. Wood took a little crucible, placed it on a stand, and put the gas-burner beneath it.

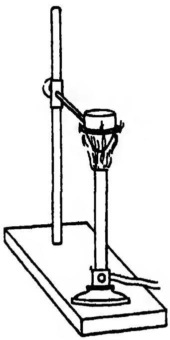
In a short time the crucible was red-hot. He then put in some of the mixture a little at a time.

The boys looked into the crucible, and noticed that, each time some of the mixture was thrown

in, there was first a pale bluish flame, and then a bright glow.

When all the mixture had been put in, the gas-burner was removed, and the crucible allowed to cool.

Mr. Wood now turned it over, and out fell a lump of black substance that looked something like a piece of coke. "Look at this," said he, "and tell me whether you can see any iron or sulphur."



Formation of Iron Sulphide.

The boys examined it closely, using the magnifying lens, but all of them said they could not distinguish either.

"I think they must have combined and formed a new substance," said Tom.

"Yes, that is so. The iron and the sulphur are both in this new substance, but they have changed in appearance and properties. The compound formed is called *iron sulphide.*"

"Is not this another example of building up?" said Harry.

"Yes, it is. The iron and sulphur are both elements; and, of course, the iron sulphide is a compound."

"And the iron sulphide weighs as much as the iron and sulphur did together," added Arthur.

"Quite right, Arthur. And now, can any of

you tell me why I commenced the experiment by weighing out forty grains of sulphur and seventy grains of iron?"

"I think I know," said Harry. "I was reading about that in my chemistry book a short time since. You did it because sulphur and iron combine in the proportion of four to seven by weight."

"That's right. You can *mix* substances in any proportion, but they always *combine chemically* in certain fixed proportions."

"If I had mixed the sulphur and iron in any other proportion than four to seven, a portion of the one which I had in excess would not have formed part of the iron sulphide. If I had had too much sulphur, the excess would have burnt and gone off into the air; if too much iron, the excess would have remained unchanged in the crucible."

7. MATTER CANNOT BE DESTROYED.

Mr. Wood had told the boys, at the end of the last lesson, that he intended to prove to them, on the next occasion, that matter could not be destroyed. So, while waiting for their instructor, they spent the time in talking the subject over.

Harold was certain that they were misinformed. *He* could destroy many things. He could make a

chocolate-cream vanish in a moment, he could turn gunpowder into smoke, he could burn a "guy", and do many other things of the same kind.

But Mr. Wood, who now entered the room, had overheard Harold's remarks, and at once corrected him.

"When your chocolate-cream vanishes," said he, "the matter of which it is composed is not destroyed. The sweatmeat dissolves in your mouth, so that you can no longer feel any solid substance; and the liquids in the body act on it and change it. Still, every particle of it continues to exist in some form or other.

"When you set fire to gunpowder, a cloud of smoke is formed. This smoke consists of solid particles, and if they were all collected and weighed, together with the gases formed at the same time, it would be found that nothing had really been destroyed. The same is true also of your burnt guy."

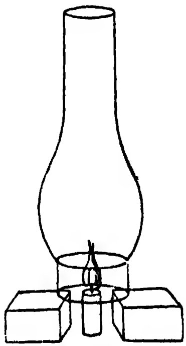
"I should like to see somebody, on the fifth of November, collecting together all the smoke and gas rising from our burning guy," said Harold, laughing.

"Even that is possible; but I suppose you will agree that it would be more convenient to choose an object smaller than your monstrous 'guy', and that's just what we are going to do."

The other boys smiled at the rebuke given to Harold, and the experiments at once began.

"Light this little candle, Bob; and, Tom, you see if this lamp-glass is perfectly dry."

Tom declared that the lamp-glass was quite dry, and was then told to place it over the lighted candle.


Candle under raised Lamp-glass.

After a few seconds the lamp-glass was removed, and found to be covered inside with moisture.

The boys were asked for an explanation, but all their replies were wrong; so the matter had to be explained to them.

"Water is a compound," said Mr. Wood, "made up of two gases—hydrogen and oxygen. The candle contains hydrogen, and when it burns, the hydrogen combines with oxygen of the air to form water. So, you see, the hydrogen of the candle is not destroyed, but only changed.

"Now we will place a gas-jar over the lighted candle, and after a few seconds raise it, and quickly cover its mouth with a piece of glass."

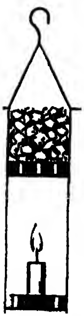
Mr. Wood did this as he spoke, and then continued:

"You see the water in the jar as before, but I am going to prove that something has now been formed besides water.

"I will pour a little clear lime-water into the jar, and shake it up with the gas formed by the burning candle.

"You see the lime-water at once turns quite milky. Now chemists have found out that, when lime-water turns milky, it shows the presence of carbonic acid gas. Where has the gas come from?

"I see I must tell you. It was formed by the carbon of the candle (for the candle contains carbon as well as hydrogen) combining with oxygen of the air. So we have now proved that neither the hydrogen nor the carbon of the candle are destroyed when the candle burns."



Apparatus for proving that matter cannot be destroyed.

"It must be a very difficult thing to weigh the gases that are formed, I should think," said Harry.

"No, not at all. I am now going to show you how it may be done.

"This glass cylinder," he continued, "which, you see, is open at both ends, has a small piece of candle in the lower part, supported on a perforated cork; and the upper part of the glass is filled with lumps of *caustic soda*.

"I will hang it on the beam of a pair of scales, and balance it exactly with weights. Now I will take out the cork with the candle attached, light the candle, and replace it.

"Can any of you tell me why the cork at the bottom is perforated, and why the top of the glass is left open?"

"It is because the candle cannot burn without

air," said Tom; "and if the glass is open both at the top and the bottom, a current of air can pass through."

"That's right, Tom; and now you see that the end of the beam supporting the glass is slowly descending, which proves that there is an increase in weight."

"How funny!" said Harold. "The candle is getting shorter, and yet it appears to get heavier."

"Well, we can hardly say that the *candle* is getting heavier, but something certainly is. You have already learnt that water vapour and carbonic acid gas are formed when a candle burns. These substances rise with the heated air till they reach the lumps of caustic soda, which absorbs them."

"But I can't see," said Harry, "why the elements of the candle should weigh any more when they reach the caustic soda than they did while in the candle itself."

"Don't you remember, Harry, that the hydrogen and carbon of the candle have combined with oxygen of the air, and that therefore—"

"Oh, of course!" interrupted Harry; "oxygen has been taken from the air, and has combined with these elements, so the weight is increased by the oxygen used up."

8. SOLUTION AND SUSPENSION.

"Last week I told you that when substances were apparently destroyed they had only changed their form, and now I will give you another illustration of disappearance, but this time without combustion or burning.

"In this vessel I have one ounce of water, and into it I will throw one dram of alum. Harry will stir the liquid with a glass rod, and you will see the alum gradually disappear."

Sure enough, as Harry stirred, the alum disappeared.

"Has it gone off in the form of vapour, as a burning substance does?" asked Bob.

"Oh no! If you taste the liquid you will find that the alum is still present in the water. But I also want to prove in other ways that it is still there.

"First let us try the weight. There, it weighs just one ounce and one dram—the same as the two substances weighed before they were mixed."

"I suppose you would call this liquid a *solution of alum?*" said Tom.

"Yes; and the alum is said to be *soluble* in water. Also, the water would be called the *solvent*, because it *dissolves* the alum."

"Some substances will not disappear in water,"

said Harold. "This piece of sulphur will not, for I tried it."

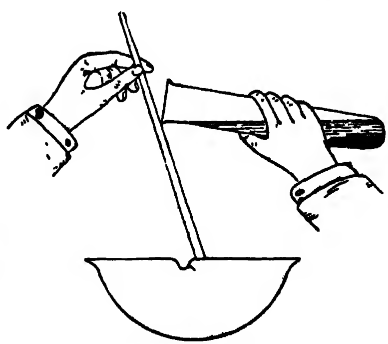
"No, some will not. But then, it often happens that a substance which will not disappear in water will do so in another liquid. For instance, your piece of sulphur would disappear in a liquid known as carbon disulphide."

"Now we will put a little powdered chalk into the solution of alum, and stir as before. But the chalk does not dissolve. Therefore, we say it is *insoluble* in water, and that it is *suspended.*

"If you look very closely into the vessel, you can see the chalk in the form of little solid pieces, moving about in the water. But the particles of alum could not be rendered visible by the most powerful microscope, for it has really become a portion of the liquid itself.

"We have now three different substances in the glass. How shall we separate them again?"

"I know how to get the chalk," said Tom; "but I can't see how the alum is to be separated."



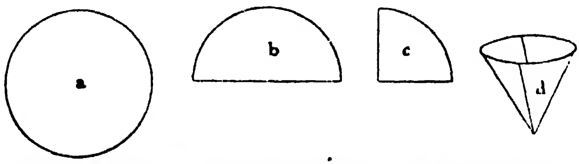
Decantation.

"Well, how would you get the chalk, Tom?"

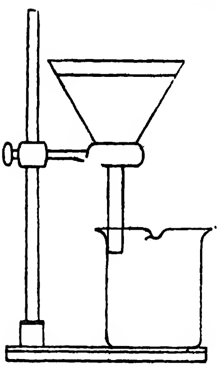
"I should let the mixture stand till all the chalk

had settled at the bottom, and then pour off the liquid very gently without disturbing it."

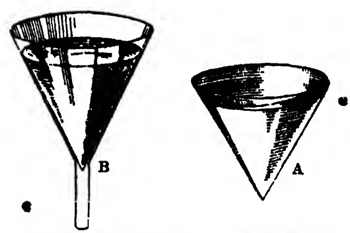
"Yes, that would do. We should call that *decanting.* But I will show you a better way."



a. Circular Filter-paper. b, Do. folded once. c, Do. folded twice. d, Opened out into Cone.



Funnel and Filter Stand.



A, Filter-paper folded into proper shape.
B, Filter-paper placed inside glass funnel.

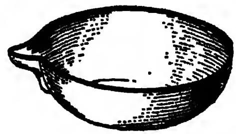
"This round piece of paper is porous, like blotting-paper; and the pores in it are so small that the smallest solid particles cannot pass through, but the water, and also whatever is dissolved in it, will pass through readily.

"The paper must be folded in the middle to make a half-circle, and then again into a quarter of

a circle. If then we open it with three thicknesses on one side and one on the other, it forms a cone that will just fit into this glass funnel.

" A little water poured on it will now cause it to keep in its place, and thus we have a filter into which we will pour the mixture."

"Oh, look!" said Harold; "the liquid runs through quite clear."



Evaporating Basin.

When it had all passed through, the boys saw the chalk on the filter; and they also tasted the clear liquid, and found that it still contained the alum.

" Now we have to get the alum out. To do this we pour the liquid into a porcelain basin, and, putting it over the gas, drive away all the water in the form of steam."

This experiment took a little time, but when, at last, all the water had gone, there was the alum quite pure and dry.

" Now," said Mr. Wood, in conclusion, " you see that water may contain two kinds of impurities—those which have dissolved, and are no longer solid; and those which do not dissolve, but exist as little solid particles suspended or floating about.

" The latter may be separated by *decanting* or by *filtering*, and the former by *evaporation*, that is, by driving off the water in the form of steam or vapour "

9. MAKING CRYSTALS.

"Our lesson to-day is to be on crystals and the methods of forming them; but first of all I want you to observe something about the dissolving power of water.

"Here is some alum that has been ground to a fine powder, and I want one of you to make a solution of it, adding the alum gradually till I tell you to stop."

Mr. Wood then passed the powder over to Bob, and also supplied him with a glass vessel half-full of water, and a glass stirring-rod.

Bob put a pinch of the powder into the water, and stirred it round till all had dissolved. Then he added another pinch and stirred again, till that had dissolved also.

He then looked up to Mr. Wood as if to know whether that were sufficient, but Mr. Wood said, "Go on, Bob; I will tell you when the solution is strong enough."

Then Bob set to work again, adding alum with one hand and stirring with the other, completely dissolving each portion before adding the next, until it almost seemed as if he were never going to stop.

At last, however, he found that no more of the alum would dissolve, and then all that he added after that remained at the bottom in the form of a powder.

"That will do, Bob," said Mr. Wood. "The water will dissolve no more now, and therefore we may say that it is saturated. We call the mixture a *saturated solution of alum.*

"Now we will apply heat to the solution, and you must observe what takes place."

The vessel containing the mixture was now placed on a stand, and heated with a gas-burner, while they all watched it carefully.

It was not long before the powder at the bottom dissolved, and then Mr. Wood asked them what was to be learned from the experiment.

"It teaches us that hot water dissolves more alum than cold water," said Harry.

"Quite right, Harry; and now Bob shall continue his experiment as before, while the water is getting hot."

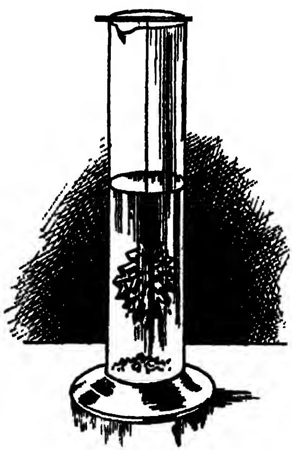
Bob went on adding alum, pinch by pinch, and they noticed that the powder dissolved now even more rapidly than before. He continued to add till the water began to boil, and even for some time after; but at last the water could take no more, for a little of the powder remained solid at the bottom.

"Now the water is saturated again," said Mr. Wood, "and you have seen that it requires a great deal more alum to saturate hot water than it does to saturate cold water."

"Is it the same with all substances that dissolve in water?" asked Tom.

"Well, no; not all. Some substances dissolve just as well in cold water as in hot, and this is the case with common salt, but usually hot water dissolves a great deal more than cold water."

"Now, who can tell me what will happen if we allow this hot saturated solution to get cold?"



Preparing Alum Crystals.

"As the water gets colder," said Harry, "it cannot hold so much; so I suppose some of it must go back to the solid state again."

"Well, we will try, and you will then see if your supposition is correct."

The glass vessel was then placed on the table to cool, and Mr. Wood tied a stone on the end of a thread, and hung it from a stick, which he placed across the top.

After a short time little glassy-looking crystals were seen on the surface of the stone, which was then removed in order that the boys might look at the crystals more closely.

The crystals were so small that the boys could hardly tell what shape they were, but when Mr. Wood gave them a magnifying-glass they could see distinctly that each little crystal had four sides, and that it came to a point at the top.

The stone was then put back into the glass again, and the crystals gradually grew larger and larger as the liquid cooled, till at last the stone was

Alum Crystals.

completely covered. A layer of crystals also formed on the bottom of the glass.

The liquid was still warm when it was time for the boys to go home, and the crystals were still growing larger, so Mr. Wood promised them that he would let the vessel remain undisturbed till their next lesson.

He also advised them to try the experiment

themselves, telling them that a glass vessel was not at all necessary, and that they might prepare a hot saturated solution of alum in any vessel by pouring boiling water on the substance, being careful, of course, not to add more water than was necessary to dissolve it.

10. CRYSTALS AGAIN.

On the following Friday Mr. Wood was in his study awaiting the arrival of the boys as usual, when he saw the little group of five (for Tom had gone to meet them on the way) loitering on the lawn.

Arthur was in the centre of the group, while the others clustered closely round him; and it was evident that they were engaged in some very interesting conversation.

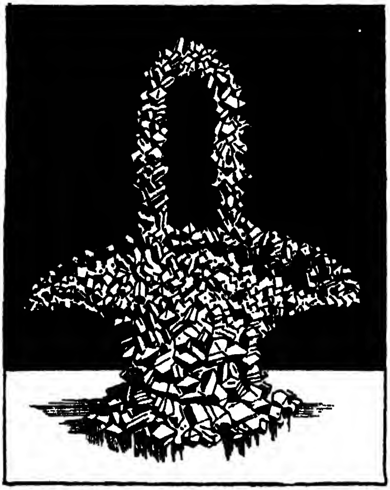
They approached the house very slowly, still busily occupied, and when at last they entered the study, Arthur approached Mr. Wood with a blush on his face, and placed on the table before him a little box, but never said a word, for he was naturally very shy, and especially so under the present circumstances.

Mr. Wood opened the box, and to his great surprise, beheld, lying on a soft layer of white wadding, a most beautiful crystal basket, of a delicate pink colour.

"Where did you get this pretty basket?" asked Mr. Wood.

"I made it," said Arthur shyly.

"You made it!" said Mr. Wood, in a tone of great surprise. "It is splendidly done. In fact, I do not think I could have made a better one myself. Tell me how you did it, Arthur."



Arthur's Crystal Basket.

"I first made a basket with bonnet-wire," said Arthur, "and then I hung it in a hot solution of alum as you did with the stone last Friday."

"Yes, but that isn't all, Arthur. I can see that the crystals are crystals of alum by their form, but alum crystals are colourless, and these are pink."

"I made one first with colourless crystals," said Arthur: "but I thought I would try another with a coloured solution, so I put a little red ink in it."

"Well done, Arthur! This is a beautiful ornament, and I will get a glass shade for it, so that you may be able to see it and yet keep it protected from dust."

It was some time before they had finished admiring the beautiful basket, and then Mr. Wood said he was going to show them another way of making crystals.

He put a crucible, with about a quarter of a pound of sulphur in it, on a stand and then placed the gas-burner beneath.

"I am not going to dissolve the sulphur in a liquid," he said: "but I will melt it by simply applying heat. Now watch the experiment very carefully."

The sulphur soon began to melt, forming a pale yellowish liquid; but it was some time before it had all changed to a liquid.

As soon as the last piece had quite melted, the whole of it was poured out into a tea-cup, where it was allowed to remain quite still while it gradually cooled.

After a short time, Bob called their attention to a number of little needle-like rods of sulphur on the surface, mostly pointing towards the middle of the cup; and Mr. Wood explained that the sulphur was now returning to the solid state as it cooled.

"In changing from the liquid to the solid state," he said, "it always assumes these needle-like forms which are crystals of sulphur.

"Now you see that the crystals on the top have grown larger and larger, so that they have formed a solid crust: and similar crystals are forming all

round the inside of the cup. Would you like to see them?"

"Oh yes!" replied all the boys eagerly.

"Very well, then, just watch what I do."

Mr. Wood then made a hole in the crust of sulphur on the top, and poured out the liquid that was beneath it. He next cut out the crust with a knife, and the boys were astonished at the sight of a layer of the most beautiful and delicate crystals of sulphur, entirely covering the inside of the cup, and all pointing towards the centre.

"What would have happened if you had not poured out the liquid from the inside?" asked Harold.

"The crystals, which were at first very small, would have grown larger and larger as the sulphur cooled, till, at last, they would have joined together and formed one solid mass.

"Now," continued Mr. Wood, "I want you all to remember that when a substance changes from the liquid to the solid state, it generally assumes regular forms which are termed crystals. Also, that the crystals of different substances are of different shapes.

"Further, you must bear in mind that there are two distinct ways of obtaining substances in a crystalline form. In one case a hot saturated solution of the substance is allowed to cool; and in the other the substance is first melted and then allowed to cool."

Part II.

COMMON INORGANIC SUBSTANCES.

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11. HOW TO ANALYSE THE AIR.

When the boys next met, Mr. Wood informed them that he was that evening going to commence a series of lessons on the chemistry of common substances.

"This time I shall tell you something about the air we breathe, and prove to you that it is not an element, but that it contains different substances mixed together.

"Into this glass basin, which contains some water, I will pour a solution of a blue vegetable substance called *litmus*. Now, you see, all the water is coloured by it.

"I now float on the water a little porcelain basin containing a piece of phosphorus; and then cover the basin with a bell-jar which, for the present, is open at the top as well as the bottom.

"You see that the blue water stands at exactly the same level inside the jar as it does outside; and, of course, when I replace the stopper of the jar, the air inside will be completely shut off from that outside. Here is a label to mark the height of the water.

"Now I touch the phosphorus with a hot wire to make it burn, and immediately close the mouth of the jar.

"Look carefully all of you, and tell me every change you observe."


Phosphorus burning in Air.

Little Bob was the first to speak. "The water is rising in the basin," he said.

"Yes," added Tom; "and it is going down inside the jar."

"Of course, if the water rises in one place, it must fall in the other, for the total quantity remains exactly the same. But can you tell me the cause of this change?"

Harry knew, for he had read about that experiment. "The heat of the flame warmed the air inside and made it expand," he said, "and so some of the water was forced under the edge of the jar to the outside."

"Yes, that is—"

But here Mr. Wood was interrupted by a remark from Harold, who said, laughing, "Why, it has all gone back again!"

And so it had. And not only had the water, both inside and outside the jar gone back to the level at which it first stood, but now it began to rise *inside* and fall *outside*.

Bob called attention to the white "smoke", as

he termed it, that now filled the bell-jar, but he was informed that the white substance was not smoke, but a solid compound formed by the phosphorus combining with one of the gases of the air.

"Now, Arthur, what further change do you observe?"

Arthur had not, as a rule, much to say, but Mr. Wood saw that he was evidently thinking about something in connection with the experiment.

"I see that the liquid inside the jar is gradually turning red," he said, "while that outside remains blue; and I was wondering whether the change is due to the new substance formed."

"You are quite right, Arthur; the phosphorus is combining with oxygen in the air, and the white compound formed is called *phosphorus oxide.* This oxide is readily soluble in water, and when it dissolves it forms an acid substance.

"That is why I coloured the water with litmus. Litmus is turned red by acids, and the change to that colour is a proof that an acid has been formed."

The water had now ceased to rise in the bell-jar, and the white substance was rapidly disappearing.

"The phosphorus is no longer burning," said Harry. "I suppose that is because all the oxygen has been consumed."

"Yes, I was careful to put into the little floating vessel more phosphorus than could be made to burn in the air which the jar contained, and now you see

that when the combustion ceases the water stands about one-fifth way up the jar, measuring from the level at which it stood at first."

12. ABOUT NITROGEN.

By the time the boys had concluded their remarks about the experiments, the gas that remained in the bell-jar was quite clear; and Mr. Wood told them they would now examine it, to see what they could learn about it.

"Can you tell me what will happen if I remove the stopper of the jar?"

No one could tell.

"Well," said Mr. Wood, "in the first place, air will go into the bell-jar, to take the place of the oxygen that was burnt up by the phosphorus. There will then be the same pressure on the water inside as there is on the water outside, and so the water, which was forced up into the jar by the greater pressure outside, will go back again.

"But I am not going to remove the stopper, simply because I do not want air to enter the jar. I will pour water into the basin outside the bell-jar till the water outside reaches the same height as that inside the jar, and then if I remove the stopper there will be no change of level and, accordingly, no air will pass into the jar."

Mr. Wood poured in water as he spoke, and when the desired level was reached, "See," he said, "the two levels are now the same; so I will open the jar and thrust into it a lighted taper."

"Why, it's gone out!" said Bob.

"Yes, and that proves that the gas which remains in the jar after the oxygen has been taken away does not support combustion. And, of course, you observed that it did not itself burn. So we may conclude that we have in air another gas than oxygen. It has been proved also that this gas will not support life. An animal placed in it would live only a few minutes, and even plants would soon die if surrounded by such an atmosphere."

"What is the name of this gas?"

"It is called *nitrogen*; that name having been given to it because it is one of the elements of the salt called nitre or saltpetre."

"What is the use of nitrogen in the air," asked Harold, "if it will not support life?"

"Its use is to dilute or weaken the oxygen. Oxygen is the great supporter of life in the air, but we could not live long in an atmosphere composed entirely of such a powerful gas as oxygen; the nitrogen makes the air exactly suited to our needs.

"Are there not other gases besides these two in the atmosphere?" asked Harry.

"Yes, there are several others, but they are all

present in much smaller quantities. Two of them are really important, and we shall talk about them in a future lesson, but the others are present in such small quantities that it is not always easy to detect them."

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13. HOW TO MAKE OXYGEN.

On the next visit to Mr. Wood's house, the boys found the table occupied by a quantity of mysterious apparatus and vessels.

Harold was just saying, "We are going to have something good to-day," when their instructor entered the room, and, after the usual greeting, informed the boys that the lesson was to be about oxygen.

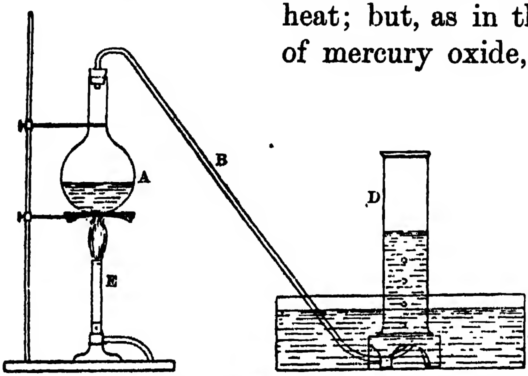
"I have already shown you how oxygen may be prepared," he said; "do you remember how it was done?"

"I do," said Tom. "You did it when you were breaking up mercury oxide into its elements. You put a spark into the tube to prove that oxygen was given off."

"Quite right, Tom, but I am not going to make oxygen by that method to-day. It requires considerable heat to drive off oxygen from mercury oxide. We shall be able to prepare it at a much lower temperature, and the materials we shall use are much less expensive than mercury oxide.

"This white substance is called *potassium chlorate*; it contains a large quantity of the gas we require. The black powder in the other bottle is *manganese oxide*, and that also contains oxygen.

"In both cases the oxygen may be driven off by heat; but, as in the case of mercury oxide, much



Apparatus for preparation of Oxygen. A, Glass flask; B, Delivery-tube; C, Pneumatic trough; D, Glass cylinder; E, Bunsen burner.

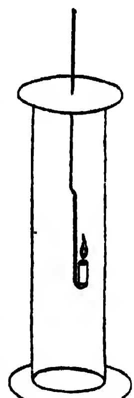
heat is necessary. When, however, a mixture of both *potassium chlorate* and *manganese oxide* is used, the potassium chlorate gives up its oxygen at a much lower temperature than it does when heated alone, so that an ordinary glass flask may be used without any danger of being melted."

The two compounds were now mixed in equal proportions on a sheet of paper, and the mixture was put into a glass flask.

The flask was fitted with a cork, and with a long bent tube which led into a trough of water when the flask was fixed on its stand.

A jar was next filled with water, inverted, and placed on a shelf below the surface of the water. This was done in such a way that no air could enter the jar. By this means it was kept full of water though upside down, the pressure of the air on the water outside not allowing any to run out.

Heat was then applied to the flask, and immediately bubbles of air were driven out. These were allowed to escape; but in a minute or so bubbles of oxygen gas came off rapidly, and then the end of the tube was placed under a hole in the shelf, so that the gas could rise in the jar.



A Candle burning in Oxygen.

As the oxygen entered, it drove the water out, and in a short time the jar was quite full, and was then closed with a glass plate and placed upright on the table.

Other jars were dealt with in a similar manner, till at last there were five jars full of oxygen, all standing in a row on the table, and still the gas was coming off rapidly.

"Now," said Mr. Wood, "before I use the gas in the jars, I will perform one experiment with the gas that is still coming off."

He then raised the tube out of the water, and placed a glowing match in the stream of gas, close against the end of the tube. Immediately the

match burst into a flame, and burnt brightly and quickly.

"Is that the gas burning so brightly?" asked Harold.

"No, the gas does not burn at all, for you see there is no flame when I take the match away. It supports combustion; that is, it enables other substances to burn, but is not itself combustible."

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14. EXPERIMENTS WITH OXYGEN.

Some very interesting experiments were then performed with the gas in the jars.

The first was this: A piece of candle was lighted and placed on a wire support, and was then lowered gently into one of the jars of oxygen.

It burnt very brilliantly, much more brightly than a candle does in air, but it was only for a short time, for most of the gas was soon consumed, and so the combustion could go on no longer.

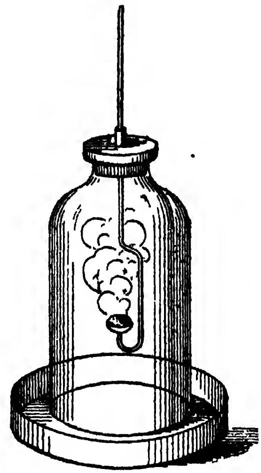
"Now, who can tell me what chemical change has taken place in the jar?" asked Mr. Wood.

"Carbonic acid gas has been formed," replied Harry promptly. "That happens when a candle burns in air, so I suppose it is just the same when a candle burns in oxygen."

"That's right, Harry. Carbonic acid gas is formed by the carbon of the candle combining with

oxygen; and water is also formed, for the candle, you remember, contains hydrogen as well as carbon."

"We cannot well prove that water was formed, because the jar was already wet before the candle burned; but you can see that carbonic acid gas is present, for when I shake up lime-water in the jar it is turned milky."


Sulphur in a Jar of Oxygen.

Mr. Wood now proceeded with the next experiment. He put a little flowers of sulphur into a small spoon on the end of a long wire, lighted it, and then passed it into the second jar of oxygen.

At first the sulphur burned with a very feeble blue flame, so feeble that it could hardly be distinguished in the daylight; but when it entered the jar of gas, it at once burst into a very bright blue flame.

After the combustion was over, the boys were allowed to smell the gas thus produced. It was a very powerful and suffocating gas, the same that is produced when sulphur-tipped matches are struck.

Into the third jar Mr. Wood put a piece of charcoal. The charcoal was first placed on a spoon like that used for the sulphur. It was then held in the gas flame till there was a little glowing spot

in one corner of it. Then it was passed into the oxygen, and at once became very bright all over, and threw off a number of brilliant sparks.

But soon the oxygen was nearly exhausted, and the carbon became dull and black again.

"What gas is formed this time?" asked Mr. Wood.

Then Harold, wishing to be first with his answer, called out somewhat hurriedly, "Water and carbonic acid gas."

"No water this time, Harold. Don't you know that carbon is an element—that it consists of nothing but carbon. Water is formed by the combustion of *hydrogen*, and that was not present in our last experiment. Carbonic acid gas only was formed."

A piece of lighted phosphorus was put into the fourth jar of oxygen, and it burned with such brilliancy that their eyes were dazzled.

The jar was also filled with dense white fumes of *phosphorus oxide*—the same substance that was formed when they burned phosphorus in the air in order to consume the oxygen and leave the nitrogen.

They now came to their last experiment. A piece of iron wire was bent into a spiral and fixed in a piece of wood large enough to cover the mouth of the jar.

The lower end of it was then heated and dipped

while hot, into a bottle of flowers of sulphur. A little of the sulphur stuck to the hot wire, and this was lighted, and the wire was immediately passed into the remaining jar of oxygen.

The sulphur soon burned out, but it made the wire very hot, which then commenced burning.

Iron burning in Oxygen.

"That is a pretty experiment," exclaimed Tom, as the iron wire gradually consumed away, throwing off a shower of very brilliant sparks. "What is that substance that falls to the bottom, and then turns black as it cools?"

"That is iron oxide—the same substance that is formed when iron is heated in an ordinary fire."

Then Mr. Wood, in conclusion, told them to remember that oxygen was a very powerful supporter of combustion, and that substances burn much more brilliantly in it than in air.

15. THE AIR IS A MIXTURE, AND NOT A COMPOUND.

The boys arrived before they were really due on the following Friday, and they found Tom and his father busy at an experiment.

At first they thought they must be late, and

were sorry to have missed part of the lesson; but Mr. Wood said to them: "No, you are not late. I shall require a jar of nitrogen for one of our experiments to-day, but, as you have already seen how to prepare it, I thought I would get it ready before you arrived."

He had just burnt a piece of phosphorus in a jar of air in order to consume the oxygen, and thus obtain the nitrogen by itself.

"But", said Harry, "you told us that there are several other gases in the atmosphere besides oxygen and nitrogen. Are not these still present in the jar?"

"Well, partly so," replied Mr. Wood; "but the total quantity is so small as not to interfere in any way with the result of our experiment."

After a few minutes the experiment was over. The oxygen had combined with the phosphorus, and the white oxide formed by the combination had all disappeared in the water, leaving the nitrogen quite clear, with, of course, the water in the jar about one-fifth above its former level. And now the lesson commenced.

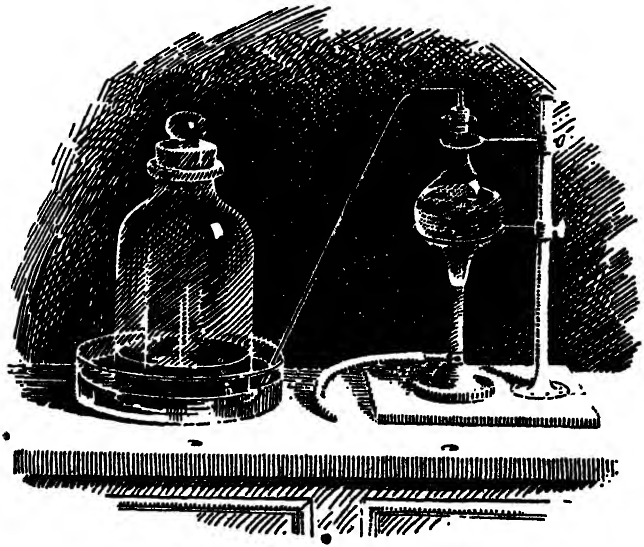
"We have next to learn whether the two gases of the atmosphere are simply mixed together or whether they are chemically combined."

"I should say they are mixed," said Arthur.

"And what reason have you for thinking so?"

"You have taught us that, when two elements

combine, the compound formed is of a different character from its elements. And in the air the properties of the oxygen and the nitrogen are not lost, but only slightly altered."



Passing Oxygen into a Jar of Nitrogen.

"Very good; but explain more fully what you mean."

"Well, the oxygen still supports combustion, and the inactive nitrogen which is present only dilutes and weakens it."

"That is quite right; and such being the case, if I pass just sufficient oxygen into this jar to replace that which was consumed by the phosphorus, we

shall then have a mixture exactly like the outside air."

"I should think so," said Arthur.

"Then we will try it. Of course you know how to prepare oxygen; we have done that before. This flask contains the same mixture as we used for that purpose last time, and, on applying heat we soon get sufficient oxygen into our bell-jar to cause the water to descend to its first level.

"Now the jar contains the two gases oxygen and nitrogen in just the same proportion as that in which they exist in the air.

"We will allow a minute or so for the two gases to thoroughly mix, and now I will put a lighted candle into the jar. There, you see, it burns just as in air—no brighter, but just as bright.

"We have yet another reason for regarding the air as a mixture and not a compound. It is this:—When elements combine chemically to form a compound, they always unite in certain fixed proportions, so that the composition of any one compound is *always* exactly the same; but the composition of the atmosphere is found to be slightly different at different times."

16. OTHER GASES IN THE ATMOSPHERE.

"In our lessons lately," said Mr. Wood, "we have been studying the two chief gases of the atmosphere—oxygen and nitrogen,—the former of which forms about one-fifth and the latter about four-fifths of its volume; and now, we will learn something about those gases which exist in the air in smaller quantities.

"Two of these are very important, as they are absolutely necessary for the support of life. They are water-vapour and carbonic acid gas."

"But is water-vapour always present in the atmosphere?" asked Bob.

"Yes, it is always present, but the quantity is constantly changing. Here is an experiment by which we may detect it. This watch-glass contains a substance called *calcium chloride*, and I will balance it exactly in this pair of scales. The calcium chloride absorbs water-vapour readily, so much so as to become completely dissolved in time. We will let it remain while we proceed with our lesson, and you will observe, before you leave, that the pan containing the chloride has gone down on account of the weight of the water absorbed."

"Are there any other substances that absorb water-vapour from the air?" asked Harry.

"Yes, there are many. Common table-salt will do so, but calcium chloride and sulphuric acid are

those most generally employed by chemists when it is required to extract the water-vapour from air or from any gas."

"How does the water-vapour get into the air?" asked Bob.

"It is always rising from the surface of water and from the ground. It is also given off in large quantities from plants, as well as from the breathing organs of animals.

"Now I will prove that the air contains carbonic acid gas. You will remember that when this gas is shaken up with lime-water, the lime-water turns milky in appearance. This is owing to the formation of *calcium carbonate*, a substance of exactly the same composition as chalk.

"If a large volume of air were made to bubble through lime-water the same change would take place, but the proportion of carbonic acid gas in the air is so small that it would take a very long time to turn the lime-water milky.

"Perhaps the simplest way of showing the presence of this gas in air is to leave a watch-glass or other shallow vessel of lime-water exposed for some time. Here is one which I filled with clear lime-water just before you arrived, and now you can see a thin film of calcium carbonate on the surface."

"You haven't told us yet where the gas comes from," said Harold.

"No, I have not, but I suppose that you all remember that it is formed by the combustion of carbon or of substances containing carbon. It was formed when we burnt a candle and when we burnt a piece of carbon in oxygen, and the same chemical change takes place when these substances burn in air. And as coal, wood, coal-gas, petroleum, and other combustible substances we burn for heating and lighting purposes all contain carbon, you will see that a large quantity of carbonic acid gas must be formed in our houses, furnaces, and factories.

"Carbonic acid gas rises in large quantities from the ground, in some volcanic districts, and we shall presently learn that it is given off by animals in breathing.

"The remaining gases of the atmosphere are present in such small quantities that they are not generally easily detected."

17. HOW ANIMALS AFFECT THE COMPOSITION OF THE AIR.

"We have already had several lessons on the atmosphere and its gases, but we have something yet to learn about the changes which animals and plants produce in the composition of the atmosphere.

"I will pour some clear lime-water into this glass, and, Bob, you shall blow into it through a glass tube."

Bob continued to blow through the tube for about a minute, while his companions watched the bubbles rising through the liquid.

"Oh, look!" exclaimed Harold; "the lime-water is gradually turning milky. I think I know what makes it change."

Blowing Air from the Lungs through Lime-water.

"Well, explain it, Harold."

"Carbonic acid is formed in Bob's lungs, and that combines with the lime in the water, forming calcium carbonate."

"Nearly right, Harold. In fact, you are quite right as far as the change which takes place in the glass, but the carbonic acid gas, instead of being formed in the lungs only, is really formed in the blood in all parts of the body.

"Some of the oxygen of the air taken into the lungs is absorbed by the blood, and is then carried by that fluid to the various parts of the body. In this way it is brought into contact with compounds containing carbon, and the two elements combine, forming carbonic acid gas.

"This gas is then brought back to the lungs, and breathed out into the atmosphere."

"I thought the air given off in this way consisted entirely of carbonic acid gas," said Harry.

"Oh no! You will remember that the air breathed into the lungs consists of only about one-fifth oxygen, the remainder being chiefly nitrogen. Only about a quarter of this quantity of oxygen is absorbed into the blood, while all the nitrogen is returned to the air unchanged. And the amount of carbonic acid gas breathed out is about the same as that of the oxygen absorbed."

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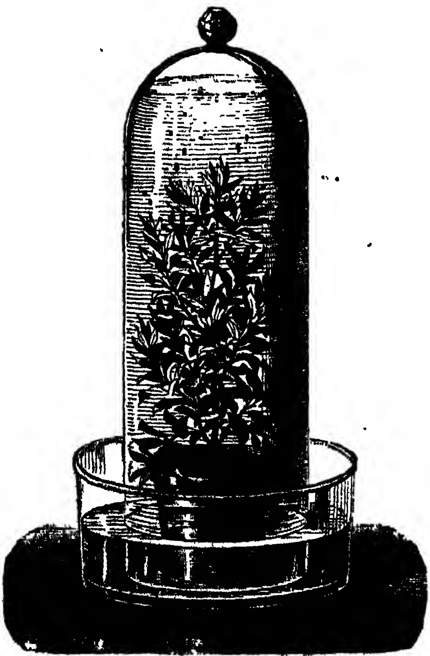
18. HOW PLANTS AFFECT THE COMPOSITION OF THE AIR.

"We have now to learn how plants affect the chemical composition of the atmosphere, and in order to show you this I have prepared two experiments.

"It would be impossible for me to show you the whole of these experiments from beginning to end during the short time our lesson lasts, as plants work their changes slowly, so I had to arrange them some time before you came, in order that you might be better able to see the results.

"You will observe that this plant is entirely covered with water, but that the bell-jar is not quite full.

"I placed the plant in the bell-jar early this morning, and completely filled it with water. I then inverted it in the glass basin, and put it in the window, where the sun could shine on it nearly the whole of the day.



Liberation of Oxygen from a Plant in Water.

"Bubbles of gas were soon formed on the leaves, and these rose to the top as they became larger, in that way producing the whole of the gas that is now in the upper part of the jar."

"Would that gas have been formed if the plant had not been placed in water?" asked Harry.

"Oh yes! My only reason for filling the bell-jar with water was to let you see how much gas had been formed, which, of course, I could not have done if the jar had been full of air from the beginning.

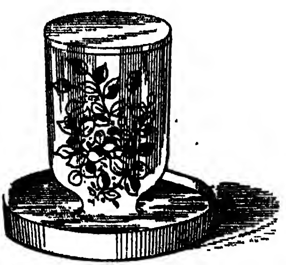
"I will now get the gas out and test it, that you may know of what kind it is."

Mr. Wood then plunged the bell-jar, plant and all, into a large trough of water; and, keeping it all below the surface, he transferred the gas into a small gas-jar, which he then closed with a glass plate.

The gas-jar was then put on the table, and a smouldering taper put into it. The taper at once burst into a flame, and burnt brightly.

"I know what gas that is," said Harold. "It is oxygen."

"That is right, Harold; the gas is oxygen, and the experiment shows you that plants give out the same gas that animals require.



Oxygen obtained from Carbonic Acid Gas by the action of Plants.

"Now, here is another plant, which I put into a jar of carbonic acid gas this morning, and which has also been exposed to sunlight all through the day.

"I will turn over the jar, and put a lighted taper into it. There, you see the taper burns in the jar, showing that at least some of the gas has been changed into oxygen, for carbonic acid gas does not support combustion.

"I hope you will try these experiments at home. Small plants are just as good for the purpose as

large ones; they need not have any soil for the time being, and the only apparatus required is a tumbler or glass jar standing in a saucer of water."

"It seems, then, that plants breathe just in the opposite way to animals," said Harry.

"Not exactly that," said Mr. Wood. "Plants *breathe* just as we do, taking in oxygen and giving out carbonic acid gas. But this affects the atmosphere very slightly indeed.

"They absorb carbonic acid gas as a food, and after decomposing it, keep the carbon and give off the oxygen, and this change affects the composition of the air much more than their breathing."

19. THE COMPOSITION OF PURE WATER.

Mr. Wood commenced his next lesson by asking the boys whether water was an element or a compound.

"It is a compound," said Harry. "You told us in one of our former lessons that it was composed of oxygen and hydrogen."

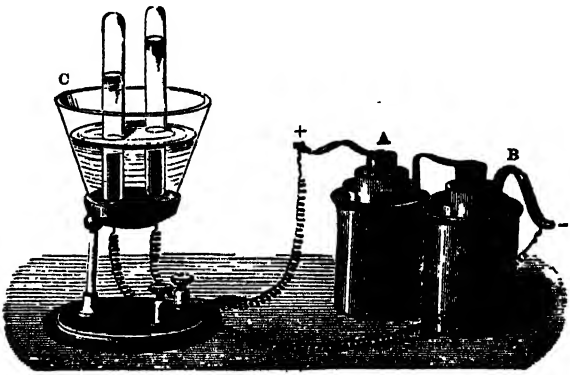
"Yes," added Tom, "you showed us that, when a candle burned, its hydrogen combined with oxygen in the air, forming water."

"Very good; and now I am going to show you two other experiments that teach us something about water and its elements.

"Here is a galvanic battery. The two wires from it pass through the bottom of a vessel containing water. When the battery is working, electricity passes along the wires into the water, and breaks it up into its two elements.

"Over the ends of the wires are two inverted tubes, both quite full of water.

"I will now set the battery working, and



Decomposition of Water by Electricity. A B, Two-cell battery producing an electric current; C, Glass-basin and test-tubes containing water.

immediately you see very small bubbles of gas rising from the end of each wire into the tube that covers it."

"The gas is rising faster in one tube than in the other," said Bob.

"Yes, and after a time you will be able to see that one tube contains just twice as much as the other; and if we were to perform the experiment a

number of times, and carefully measure the quantity of gas in each tube, we should always find the gases in the exact proportion of two to one."

"And that is a proof that water is a chemical compound and not a mixture," said Tom.

"Yes, it is, for I have told you before that the composition of chemical compounds never varies.

"You see that one tube is now half-full, and the other a quarter full. That is quite a sufficient quantity of each to test. We will take the tube with the smaller quantity first. I will close the bottom of the tube with my thumb before taking it out of the water, and then turn it over to get the gas at the mouth."

Mr. Wood then thrust a glowing match into the gas, and the match immediately burst into a bright flame, showing that the gas was oxygen.

He then repeated the experiment with the other tube, but used a burning match instead of a spark, and the gas itself began to burn with a feeble blue flame, but the match would not burn in it.

"This gas is hydrogen," he said, "a gas about which we shall soon learn more."

He then proceeded with the second experiment. He took a strong bottle—a soda-water bottle—filled it with water, and inverted it in a trough of water.

Next, he made some hydrogen gas, and passed it into the bottle till it was about two-thirds full

and then he prepared some oxygen, and passed that in till the bottle was just full.

The bottle was then corked, removed from the trough, and inverted a few times in order that the two gases might quickly mix, for one was much lighter than the other, and therefore had a tendency to remain at the top for a short time.

Now the cork was drawn, and the mouth of the bottle was held close to the gas-burner, while all the boys were quietly watching for the result.

Bang went the gas; and the five terrified boys were almost afraid to look around to see what damage had been done. But when they saw Mr. Wood enjoying a good laugh, they knew it was all right, and began to smile themselves.

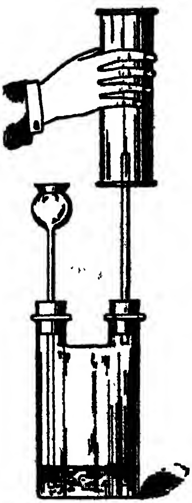
"I showed you this experiment," he said, "in order to let you see what a powerful attraction existed between these two gases. When I put the mouth of the bottle near the gas light, the heat caused the two gases to combine with violence, and the result was the formation of water-vapour."

20. HYDROGEN.

"We have seen that one of the gases of the atmosphere is also one of the elements of water, and we have prepared that gas (oxygen) and illustrated its properties. We shall now prepare

hydrogen—the other element of water—and see what we can learn of *its* properties.

"For this purpose we can use either a bottle with two necks, called a Woulffe's bottle, or a wide-mouthed bottle with two holes in the cork. This arrangement is not really necessary, for any kind of bottle may be made to answer the purpose; but it is a great convenience to have a funnel, so that while the gas is still coming off, we may be able to add the acid required, a little at a time, without allowing air to enter the bottle."



Apparatus for preparing Hydrogen.

"But will not the gas pass out through the funnel as well as through the tube?" asked Harry.

"No; and if you look at our apparatus you will see that it cannot. Don't you observe that the long stem of the funnel passes to the bottom of the bottle, and there it dips into the liquid?"

"Oh, yes; and the liquid prevents the gas from escaping."

"What is that in the bottle?" asked Bob.

"The solid substance is the metal zinc, and the liquid is a mixture of sulphuric acid and water. As soon as the acid touches the zinc, hydrogen

gas passes off rapidly. You can now see the bubbles rising through the liquid.

"I will apply a light to the tube presently, that you may see the hydrogen burn, but it would not be safe to do that now, as a mixture of hydrogen and air is very explosive, and all the air has not yet been driven out by the gas.

"I will collect some of the gas in a jar, and show you that it is mixed with air."

Mr. Wood then held an inverted jar over the tube through which the gas escaped from the bottle, and after about a minute he held it near a light.

A flash of light was then seen, and this was accompanied by a loud sound like a short howl, which startled the boys.

"That's a queer sort of explosion," said Harold; "I thought it would be more like the sound of a gun."

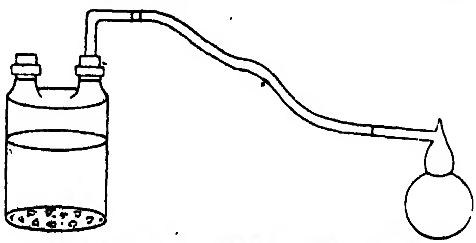
"So it would have been, Harold, if the gas had been in a corked bottle. In any case, the rapid combustion of the hydrogen, which was the cause of the explosion, proves that the gas was mixed with air; and that, therefore, it would be dangerous to apply a light to the tube. But it is probable that the air has, by this time, been all expelled; so we will collect some more gas, and try it again."

This was soon done, with the result that, after a slight noise, due to the combustion of the hydrogen at the mouth of the jar, where it was mixed with

air, the gas burned silently, with a pale-blue flame.

"That shows that the hydrogen in the bottle is no longer mixed with air; and I may, therefore, apply a light to the tube."

The gas now burned at the mouth of the tube, at first with a pale-blue flame, but this was changed



Blowing Soap-bubbles with Hydrogen Gas.

after a few seconds to a yellow flame, which Mr. Wood explained, was due to sodium in the glass.

"Why did you not collect the hydrogen over water, as you did the oxygen?" asked Harry.

"That might have been done, Harry; but when a gas is either much lighter or much heavier than air, it may be easily collected by the displacement of the air. Of course, you cannot be sure of the exact moment when your jar is full, but that does not matter in the present instance."

"I think I read that hydrogen is the lightest of all the gases," said Harry.

"Yes, that is so. It weighs only about one-fourteenth as much as air, which explains how it is

that these soap-bubbles, blown with hydrogen, rise so rapidly in the air."

As Mr. Wood was speaking, he caused the gas to blow soap-bubbles, which rose to the ceiling of the room; and Harold, who was always ready for fun, was called upon to light others as they ascended.

Hydrogen burning; taper extinguished.

A little toy balloon was also filled with hydrogen, and this rose to the top of the room, and was still there when the boys went home. And, as another illustration of the lightness of hydrogen, the gas was poured *upward* from one vessel into another; the vessel to be filled being, of course, inverted.

"I have one more experiment for you," said Mr. Wood; "I am going to plunge this lighted taper into a jar of hydrogen."

The jar was held mouth downwards, and the taper thrust into it. The gas burned as before, at the mouth of the jar, but the light of the taper was immediately extinguished.

"This experiment teaches us that, although hydrogen itself burns, yet it does not support the combustion of the taper. And you have seen, too, that the hydrogen itself can burn only at the mouth of the jar, where it is in contact with the air."

"I have noticed something more," said Bob.

"Well, what is it?"

"Every time you lighted hydrogen in a jar the jar became wet inside."

"That's very good, Bob; and now perhaps Harry will be able to give us the reason."

And Mr. Wood was right; for Harry was able to tell them that when the hydrogen burns it combines with oxygen of the air, and forms water.

21. RAIN-WATER, SPRING-WATER, AND SEA-WATER.

At the next meeting Mr. Wood told the boys they were to have another lesson on water.

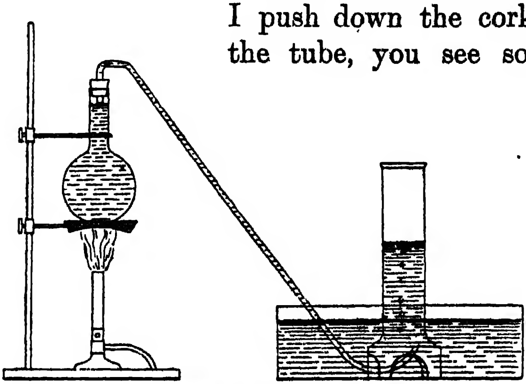
"You have learnt what the composition of pure water is," he said, "and you know the properties of the two elements which compose it. Water, however, is never found quite pure, but often contains large quantities of dissolved and suspended matter."

"*Rain-water* is quite pure, is it not?" said Arthur.

"No, Arthur, not quite. Rain-water is formed from the clouds, and the clouds are formed from the water-vapour in the air. This vapour rises in a pure condition from the surface of the sea and moist land, for, when water evaporates, it leaves its impurities behind; but the very small particles of water which form the clouds, and the rain-drops

that fall through the air, both absorb gases from the atmosphere.

"Here is some rain-water which I collected in a large pan during the thunder-storm yesterday. I will fill this flask with it quite to the top; and, as I push down the cork with the tube, you see some of



Dissolved Gases expelled by Heat from Water.

the water is forced into the tube and completely fills it.

"We will now apply heat to the water, and collect any gas that may be driven off in a gas-jar."

After a minute or two the boys saw a number of small bubbles rising in the flask and passing into the tube; and, shortly after, the water began to boil, sending a considerable quantity of gas into the gas-jar.

The gas collected was then shaken up with a little lime-water, and the milkiness produced proved that carbonic acid gas was present.

"I suppose it is not all carbonic acid gas," said Harry.

"No; the water contains a little nitrogen and oxygen, as well as very small quantities of other gases; but carbonic acid gas is dissolved more readily than the two principal gases of the atmosphere."

"Must you use rain-water for this experiment?" said Harry.

"No, we might have used water from any other natural source, for all are fed by the rain, and water from them must, therefore, contain the same gases. I will now show you another experiment with the rain-water, and this one we will perform with our drinking-water as well."

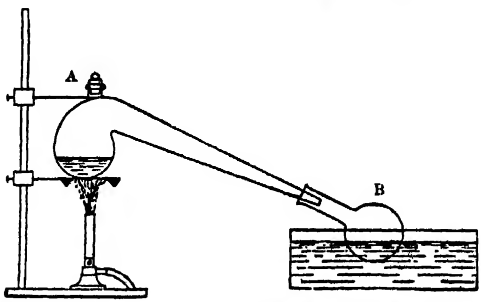
Mr. Wood then put one single drop of rain-water in a clean watch-glass, and a drop from the tap in another. Both watch-glasses were then gently warmed till the water had dried up: the one which had contained the rain-water showed no mark, but that which had held the drop of water from the house supply had a slight quantity of a whitish substance left.

"How do you explain that, boys?"

"I think I know," said Tom. "The rain-water does not contain any impurities besides the gases absorbed from the air; but the house-water comes from a river or a well, and therefore contains some substances which it has dissolved out of the ground."

"That's right, Tom. All water that has run over or through the ground takes up from it and holds in solution more or less mineral matter. Sometimes the quantity is very small—only a few grains in each gallon—but some natural waters contain large quantities of matter in solution.

"The water of the River Thames, above London,



Distillation of Water. A, Retort; B, Flask; C, Trough of cold water.

contains a little more than twenty grains of dissolved matter in each gallon. Sea-water contains nearly six ounces in a gallon."

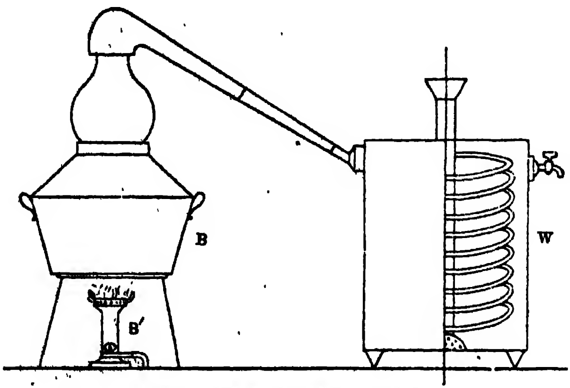
"That's why sea-water tastes so salt," said Bob; "but I've been told that you can get fresh water from salt water. How is it done?"

"It is easily done by boiling the water, and passing the steam into a cold vessel, where it is changed back to water. Of course the salts that were dissolved will be left behind in the boiler.

"Here are three forms of apparatus suitable for this purpose.

"In the first the salt water is boiled in a retort, and the steam is condensed in a flask which floats in cold water.

"In the second the steam is passed through a coiled tube which is surrounded by cold water.



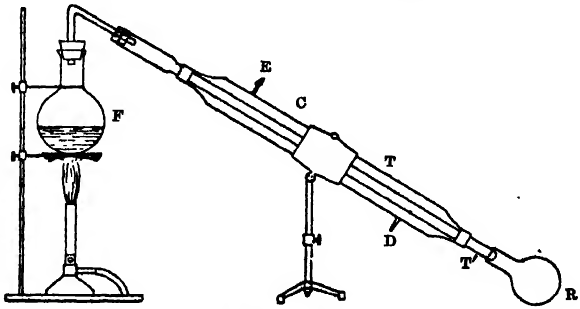
Still for preparing Distilled Water.

B, Boiler; W, Worm of block-tin surrounded by cold water; B′, Burner for heating the water.

"In the third the steam passes through a tube which is enclosed in a larger one; and the larger one has a constant stream of cold water running through it to keep the smaller one cool.

"This process of heating a substance and condensing the vapour given off is called *distillation.* The apparatus, which consists of a boiler and a condenser, is called a still; and the liquid formed by the condensation of the vapour is said to be distilled.

"We have learnt before that suspended matter may be removed by filtration, but you will see that



Another Still.

F, Flask in which the water is boiled; C, Condenser, consisting of an outer tube T and an inner tube T′. The space between the two is kept full of cold water, which is made to flow upward. D, Delivery-tube for the cold water; E, Escape-tube for the water; R, Receiver, to receive the distillate.

both suspended and dissolved substances can be removed from water by distillation."

22. CHALK, LIME, AND MORTAR.

"This evening I am going to tell you something about chalk and its uses.

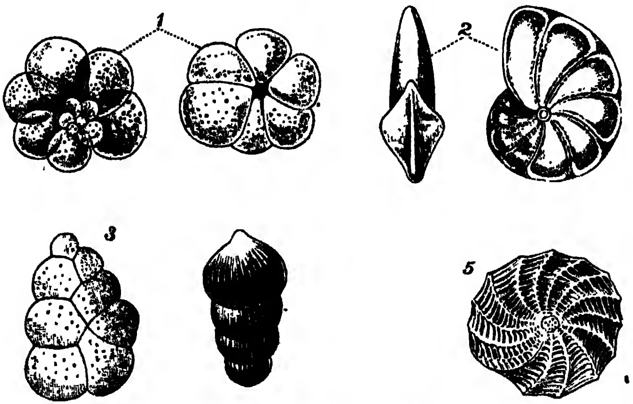
"Chalk is a soft rock, composed almost entirely of very small shells—the shells of animals that once lived in the sea; and if you examine a piece of it with a microscope, you can see these shells distinctly.

"We are not going to talk about the way in which chalk was formed, but we will learn something

of its chemical composition, and find out some of the uses to which it is put.

"I will first cut a small and thin piece of chalk, fix it in a holder, and then send a blowpipe flame on to it for a short time.

"Now see how brightly it glows, with a very



Shells from a piece of Chalk (Foraminifera)—magnified.

white light. That light is really what we call lime-light, for the chalk has been partly decomposed, a gas has been driven off from it, and lime remains."

"Will it weigh less than before?" asked Harry.

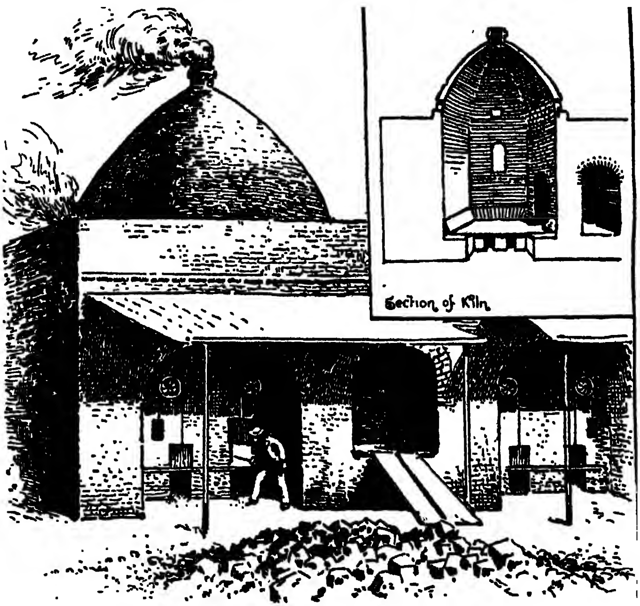
"Yes, certainly. The gas that was driven off is carbonic acid gas, which weighs almost as much as the lime that remains; thus the weight is reduced almost to one-half."

Then Tom wanted to know whether the lime his

father was speaking of was the same substance that builders use.

"It is," said Mr. Wood; "and it is prepared in the following manner:—

"A large furnace, called a limekiln, is filled up

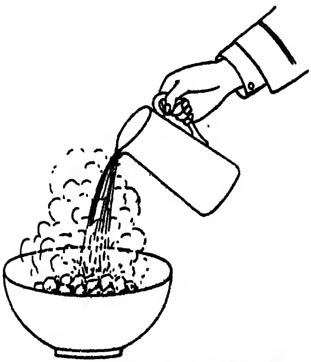


Limekiln near London.

with chalk, limestone, or marble (for all three of these rocks have the same chemical composition), mixed with some coke or coal. A fire is then lighted at the bottom, and the whole is allowed to burn for some days.

"At the end of that time the coal or coke used is entirely reduced to ashes, and the blocks of lime are removed when cold, and sold to builders, who call it *quicklime.*

"Here is a large piece of quicklime which I obtained from the builder down the road. I will put it in this dish, and throw some water on it."



Water poured upon Quicklime.

"What has become of the water?" asked Bob, when he saw the water disappear, as it quickly did.

"It has all been absorbed by the lime, just as ink is absorbed by blotting-paper, for the lime is full of little holes."

"Oh! the lime is cracking," said Harold, "and steam is coming from it."

"Yes. The lime and the water are combining, and heat is formed by the combination. Some of the water is going off in the form of steam, but most of it remains with the lime, forming a dry powdery substance, which we call *slaked lime.*"

"I have seen the builder throw water on a heap of lime," said Tom.

"The builder calls that slaking the lime, but he puts more water than is necessary to change the quicklime into slaked lime, and so he gets a wet and

pasty mixture. This mixture is then well worked up with sand, thus producing mortar for building.

"Of course you have all noticed that mortar soon gets dry and hard, and that it sticks to the stones or bricks between which it is placed.

"When exposed to air, the water which did not combine with the quicklime soon evaporates or dries up. But this is not all, for the slaked lime slowly combines with carbonic acid gas in the air, forming a hard substance called *calcium carbonate.*"

23. CARBONIC ACID GAS.

"We have already said a great deal about carbonic acid gas, and now I suppose you would like to see some made."

"Oh, yes, we should!" said Arthur.

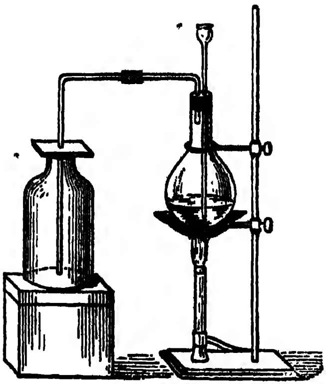
"Then you shall help me, Arthur. Break up this chalk, and put the pieces into the flask."

While this was being done, Mr. Wood poured some strong acid (hydrochloric acid) into a glass measure, and added water to weaken it.

"You see the cork is fitted with a tube, and a long funnel that goes to the bottom. And, as soon as I pour the acid down the funnel, the gas begins to come off.

"You remember that we passed hydrogen upward into a jar, because it is lighter than air; but carbonic

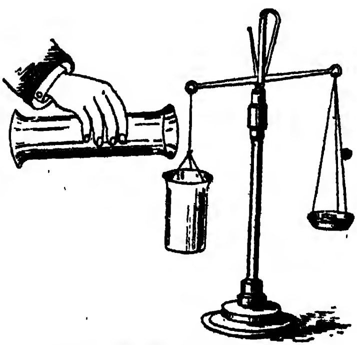
acid gas is heavier than air, and so will fall into a vessel, driving the air out at the top. Let us see if the gas-jar is full."



Preparation and Collection of Carbonic Acid Gas.

A lighted taper was then put slowly into the jar; when it got about half-way down, the flame suddenly went out.

"There, you see that the jar is only half-full; for, as carbonic acid gas will not burn, and will not support combustion, we can tell at once when the taper enters it.



Proving that Carbonic Acid Gas is a Heavy Gas.

"Now we will try again. This time the flame goes out as soon as it enters the top of the jar, and so we know that the jar is now quite full."

Mr. Wood then showed the boys two or three experiments which proved that the gas was a heavy one.

He poured the gas from one jar into another, showing by means of a lighted taper that it had really run out like water.

He then balanced a glass on a pair of scales, and poured carbonic acid gas into it; and the glass went down, showing that the gas is heavier than air.

He also filled a large vessel with the gas, and allowed a soap-bubble containing air to fall into it; and the bubble floated on the top of the gas just as a cork would float on water.


Soap-bubble in a Jar of Carbonic Acid Gas

"Now," said Mr. Wood, "I have shown you that the gas we are preparing will not itself burn, and that nothing will burn in it; but there are other gases which have these properties, so how shall I prove to you that this one is carbonic acid gas?"

"Would you not shake it up with lime-water?" said Harry. "You did that when you wanted to prove that this gas was produced when a candle burns."

"That's quite right, Harry. I will test this gas with lime-water; but instead of shaking it up with the lime-water, I will allow the gas to bubble into it from the tube."

The lime-water turned milky almost immediately, and the boys were told that the substance formed was a compound containing carbonic acid gas and

lime, and was therefore of the same composition as chalk.

"Here is another experiment with the gas," said Mr. Wood. "I will allow some of it to bubble into pure water for a few seconds. Now I will add a few drops of litmus solution to the water, and, you see, the blue litmus turns red. What does that show about the gas?"

"Ah! we have had something like that before," said Tom. "You told us that when litmus was turned red, an acid must be present."

"Yes, that is the case here. The experiment really proves two things. It shows that some of the gas must have dissolved in the water, and also that it forms an acid with the water."

24. CHARCOAL.

The next time the boys assembled for their chemistry lesson, Tom and his father were getting the apparatus ready for the experiments.

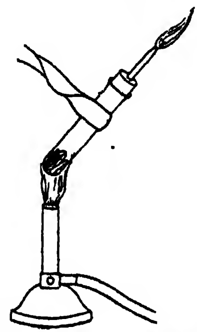
Tom was cutting up some thin sticks of wood, and putting the pieces in a test-tube which he afterwards fitted with a cork and tube, and fixed on a stand; and Mr. Wood was arranging some other apparatus, the nature of which the boys could not understand at all.

"We will have Tom's experiment first," Mr.

Wood said. *He then told Tom to put the gas-burner under the test-tube.*

The test-tube was made of very hard glass, that would not easily melt; and it soon became red-hot.

"Why doesn't the wood burst into a flame?" asked Harold, who was hoping that some brilliant result would follow.



Preparation of a Gas from Wood.

"It cannot burn without air, Harold. There was very little air in the test-tube when we first applied heat, and that little has already been driven out by the gases arising from the heated wood."

By this time there was quite a cloud of vapour and fumes shooting from the tube, and Mr. Wood proved that water-vapour was among the number. This he did by holding a cold glass over the tube, when the glass immediately became wet.

A light was then applied to the tube, and at once a large flame burst forth like that of burning gas.

"What is it that is burning?" asked Bob.

"It is gas that has been driven out of the wood by the heat. A large number of different gases are formed when wood is decomposed in this way, and, as you see, some of them are combustible."

At last the experiment was over, for nothing else would come off; and then, after the test-tube had

been allowed to cool down, Tom turned out from it a number of little sticks of charcoal.

"Now you can see that the wood did not *burn*; for, when wood is burnt, only ashes are left. It has been charred, or converted into charcoal."

Each of the boys took a piece of the charcoal and examined it. They found it very light indeed —much lighter than wood; and Harold discovered that he could write on paper with it.

"Now we will try another experiment with the charcoal. Put all the little pieces on this copper dish, and I will heat them."

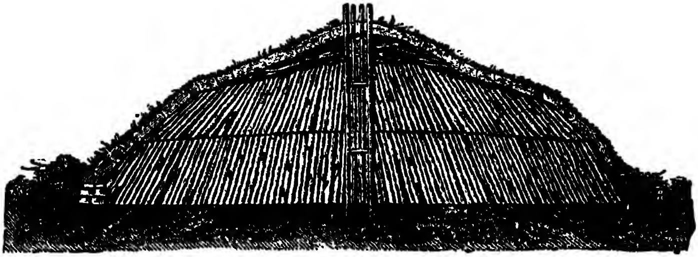
The dish was then put over a gas burner, and, when it became red hot, the charcoal began to glow. After a short time the burning was all over, and then the dish contained nothing but a little whitish ash.

"So you see that charcoal is formed when wood is heated in such a way that the air cannot get at it; but if there is sufficient air, heated wood or charcoal is all burnt away except the ash, which is the mineral substance it contained."

"How do they make charcoal in large quantities?" asked Harry.

"They make large heaps of wood, and cover them with turf and clay, leaving a small hole at the top for gases to pass out. The wood is then set alight, and it smoulders for a long time, but cannot burn."

"In that way charcoal is obtained from wood, but you must know that it can be prepared from

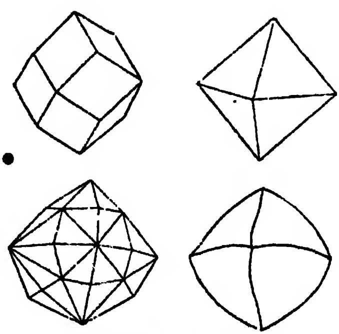


Making Charcoal from Wood. Conical pile of wood covered with turf and clay.

any animal and vegetable substances in a similar manner.

"Animal charcoal, which is used very largely for filtering and purifying various substances, is made by heating blood or other animal matter.

"I must tell you that *pure charcoal is an element.* It is one of the forms of carbon, but, made in the way you have seen, is not quite pure, for it contains a certain amount of mineral matter.



Crystals of Diamond.

"There are some other forms of this element. One is called *lampblack,* and is really a kind of soot, formed when certain substances are burned.

"Another is called *plumbago* or *black-lead.* It is the substance used for making lead-pencils and for polishing stoves; but remember that it contains no lead.

"The *diamond* is also a variety of carbon, in the form of a very hard crystal.

"We shall have more to say about charcoal and the other varieties of carbon, but we must leave the rest till our next lesson."

25. MORE ABOUT CHARCOAL.

"Of course you all know what chemical change takes place when charcoal burns, for we burnt a piece in oxygen and then proved, by means of lime-water, that carbonic acid was formed."

"Now I want you to look carefully at this apparatus. Here is a hard glass tube containing a piece of carbon. It is fitted with a smaller tube at each end. One tube passes into a vessel containing lime-water, and through the other we will pass a stream of air."

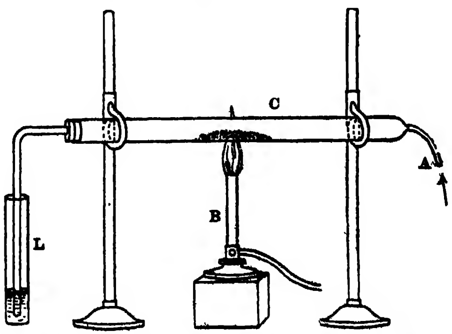
As the air was forced into the tube at one end, bubbles of gas were seen to pass through the lime-water at the other. But the lime-water did not turn milky.

"How is this?" asked Mr. Wood. "No carbonic acid gas is formed."

"You did not make the charcoal hot," said Harry.

"Quite right; and so the experiment proves that carbon will not combine with oxygen unless heated.

"Now I will put a gas-burner under the middle



Experiment to Illustrate the Combustion of Carbon.
A, Tube through which air is forced. C, Glass tube containing Charcoal.
L, Cylinder with lime-water. B, Bunsen burner.

of the tube; and, when the charcoal is very hot, I will send in some more air."

When this was done, the charcoal at once began to glow, and the lime-water soon showed that carbonic acid gas was formed.

The experiment was continued until, at last, all the charcoal had disappeared, except a little whitish ash.

"Can you show us how lampblack is made?" asked Harold.

"Yes. I will do so now."

"Some combustible substances contain a very

large quantity of carbon, but when they burn a great deal of the carbon is not consumed. So they burn with a very smoky flame, for smoke consists of small particles of unburnt carbon.

"Here is some turpentine, which burns just in

this way. I will put a little of it in a small basin, light it, and then cover it with a large bell-jar.

"Now look at the thick black smoke rising from it."

"I suppose it will not burn long," said Harry.

"No. You see it is burning more feebly already, and when the oxygen is nearly consumed the flame will go out.

"Now the combustion is all over. We will let the bell-jar remain for a short time, to allow the smoke to settle down, and then we will examine the inside."

When the jar was turned over a few minutes later, it was seen to be covered with soot, just like the inside of a chimney, only much blacker; and there was also a circle of soot on the paper where the jar stood.

"Is this lampblack?" asked Bob.

"Yes, this is lampblack. It is very useful for making black paint, and large quantities of it are prepared for this purpose, much in the same way as I have shown you; but, of course, it is not made in bell-jars."

"I should like to know one thing more," said Harold.

"Well, what is that?"

"Why, something about diamonds, of course. You say the diamond is only carbon, but how do we know that?"

"A diamond is certainly very different from any other form of carbon, but yet we know that it really *is* carbon and nothing more.

"If you burn a substance, and it produces carbonic acid gas, what does that teach you?"

"That the substance contains carbon, I suppose."

"And if the substance completely burns away, and forms nothing at all but this same gas, what would you think then?"

"Why, then, of course, there can't be anything in the substance but carbon."

"Well, that is just the case with the diamond. It burns away completely when heated in oxygen, and is converted into carbonic acid gas.

"We have not yet done with carbon; for next week I am going to give you a lesson on coal, which, as you know, contains a large quantity of this element."

26. COAL.

"It is said that coal is changed vegetable matter, that it is the remains of ferns, mosses, and other plants that lived on the earth many ages ago. But how are we to know that such is really the case?"

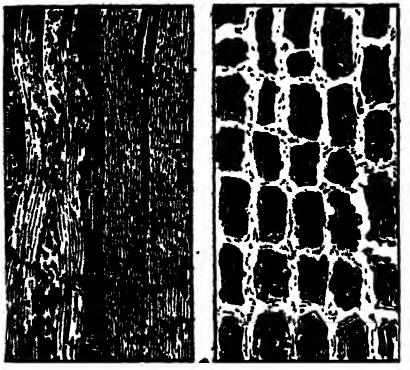
This question was put to the boys when they met for their next lesson. Harry seemed to be the only one who could tell anything about it.

He said, "I have seen pieces of coal in the shape of ferns and parts of stems that had been taken out of a coal-pit in Lancashire."

"I will show you something more," said Mr. Wood. "Under this microscope is a piece of coal which has been made so very thin that it is partly

transparent; and if you look at it through the microscope you will be able to see in it a number of little cells, which were once living vegetable cells."

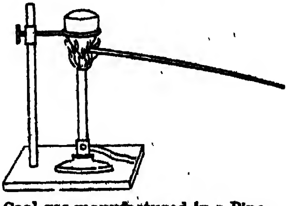
The boys were much interested in this, and when all had seen it, they eagerly watched the preparations for an experiment that was to follow.



Longitudinal Section. Transverse Section.
Coal under the Microscope.

Little Bob ground up a piece of coal in a mortar till it was in the form of coarse powder, and while he was doing this Mr. Wood took a tobacco-pipe, and fixed it on a stand.

He then put the crushed coal into the bowl, covered it with clay, and placed the gas-burner under it.



Coal-gas manufactured in a Pipe-bowl.

In a very short time gas began to escape through the hole in the stem.

"That experiment is very much like the one you showed us when you heated some pieces of wood in a tube," said Harold.

"Yes, it very similar, and the result will be almost exactly the same; and that is another reason we have for believing that coal is formed from vegetable matter.

"Now, you see a thick smoke coming out of the stem, and if I apply a lighted match, the gas that is coming off with the smoke burns brightly.

"The gas that is burning is the same as that which we burn in our houses, and it is prepared in a similar way; but it has to be purified before it is supplied to us."

A clean glass rod was then held in the flame of the burning gas for a few seconds, and when it was taken out it was seen to be quite black.

"What does this tell us about coal, boys?"

They all knew that. The black substance was soot or lampblack, which is one of the kinds of carbon, and so it tells us that there is carbon in coal.

Indeed, carbon is the chief element in coal, for it is present in much larger quantities than any of the others.

After a few minutes the gas ceased to come off. The pipe was red-hot, and so was the substance inside, but no more changes were taking place; and so the gas-burner was removed, and the pipe allowed to get cold.

"Now let us see what the pipe contains," said Mr. Wood; and he tried to shake the substance out

of it, but it would not come, and so he had to break the pipe.

When this was done, out fell a lump of black stuff, just the shape of the pipe itself.

It was passed round for the boys to look at, and they all said it was just like coke.

And it was coke. Just as charcoal is formed by heating wood, so coke, which is only another kind of carbon, is made by heating coal.

When charcoal is burnt an ash is left, showing that it is not pure carbon. In the same way, when coke is burnt an ash is left, which proves that it contains mineral substance just as wood does.

27. COAL-GAS.

"In our last lesson you learnt how to make gas from coal, and I told you that this same gas is the one we burn to give us light and heat.

"Now I shall show you some experiments by which we may learn some of its properties; but instead of making it ourselves, we will take it from the gas-pipe through an india-rubber tube.

"First, we will dip the tube into a gas-jar, turn on the gas for a few seconds, and then let the gas-jar stand with its mouth open while I fill a second jar.

"We will invert this jar, let the gas pass *upward*

into it, and then set it aside on a stand with its open mouth downward.

"Now I will put a lighted taper into the first jar, and you see there is nothing in it but air, but when I put the taper into the inverted jar we get a flame which shows that it contained some gas.

"Now tell me, boys, what you have learnt from these experiments?"

"I know one thing," said Tom. "This gas is something like hydrogen. It must be lighter than air, for it would remain only in the inverted jar."

"That is right, Tom; the gas does resemble hydrogen in many respects. Did any of you notice anything more?"

"Yes," said Harry. "While the gas was burning, the jar became wet inside, and that proves that coal-gas contains hydrogen."

"Very good, Harry. I am glad you remember that water is formed by the burning of hydrogen. Did anyone else observe a change?"

"I noticed another thing," said Tom. "When the gas burnt, the jar was blackened a little at the mouth."

"And what does that prove, Tom?"

"I suppose it proves that the gas contains carbon, Father."

"Yes, and so we have learnt that coal-gas contains two elements—hydrogen and carbon.

"Here is another way of proving the presence of

both hydrogen and carbon. I will fix a glass tube on the end of the india-rubber, light the gas, and hold a gas-jar over the flame.

"You see the jar becomes wet at once and if I

now shake up the air in the jar with lime-water, the lime-water turns milky."

"Then the jar contained carbonic acid gas," said Bob.

"Yes, and of course you know by this that carbon must have been burning."

Then Harry said, "You showed us several experiments which proved the lightness of hydrogen. Can the same experiments be performed with coal-gas?"

Mr. Wood then poured coal-gas *upward* from one jar into another, and passed some into an inverted vessel, just as he had done with hydrogen.

This reminded Harold of the soap-bubbles that went up to the ceiling, some of which he lighted as they rose, and he said he should like to see some soap-bubbles filled with coal-gas.

This was soon done. The end of the tube, through which the gas was passing, was dipped into soapy water, and the bubbles went straight up to the ceiling, but not so fast as the bubbles of hydrogen, for coal-gas is not so light as hydrogen, though it is much lighter than air.

"Shall I light some?" asked Harold eagerly.

"Yes, if you like. Here is the taper."

Harold then made a little fun by lighting some of the bubbles as they went up. They all burned with a large yellow flame, not a blue flame as the hydrogen did.

"Now, who can remember another experiment we performed with hydrogen?"

"You put a lighted taper into it," said Harry, "and the light went out."

"Yes, and you took some hydrogen mixed with air, and lighted it, and it went off with a bang," added Harold.

Both these experiments were then performed with coal-gas. In the first case the taper was put out, and in the other the gas burned very quickly, but it did not make much noise.

"Now you see that coal-gas has much the same properties as hydrogen. It is explosive when mixed with air, but not so much so as a mixture of *hydrogen* and air."

Mr. Wood concluded his lesson by telling the boys that it is very dangerous to take a light into a room where the gas has been escaping so long that a great deal of it is mixed with air, for there is considerable risk of a serious explosion occurring.

28. FLAME.

"What is the subject for this evening?" asked Harold, who was anxious to know whether they were to have another set of experiments like those they had had the week before.

"I am going to talk to you about flames this time," was the reply.

"Then are we to see bright flames, green flames, blue lights, and all that kind of thing?" asked Harold.

"Oh, no! I am simply going to tell you about candle and gas flames."

Harold looked disappointed, but the others

thought they should hear something interesting, even about such flames as these, and they were quite satisfied.

"Just look at this candle flame, boys, and notice the different colours in it."

Candle Flame.
C, Inner dark part; A, Bright part; BD, Pale-blue outer part.

"Colours in a candle flame!" exclaimed Harold. "I didn't know there were any."

"I didn't say *bright* colours, Harold; but you will see different tints if you look carefully."

They all looked steadily at the flame for a short time, and could make out three distinct parts in it.

There was a dark part in the middle near the bottom, a bright white part outside and above this, and then a pale-blue part outside this again.

"Now," said Mr. Wood, "I am going to show you the differences between these three parts of the candle flame.

"First, I will put the end of this short glass tube right into the dark part of the flame, and apply a light to the other end."

When this was done a very small pale-blue light was seen at the upper end of the tube.

"That looks as if some gas were coming out of the flame," said Tom.

"And so it is, Tom. The inner dark part contains cool and unburnt gas, which is formed from the substance of the candle by the heat, and some of that gas is passing out through this tube.

"You notice also that the glass tube has been blackened where it touched the white part of the flame, and that shows you that there must be solid and unburnt carbon there.

"This white part, in fact, contains hundreds of little particles of carbon, all white hot, and that is the cause of the light.

"Next comes the blue part. I will put the end of this glass tube just into the blue flame near the bottom, and you see that it does not get blackened at all.

"That is because this part of the flame is in contact with the air, and so there is plenty of oxygen to burn up the solid particles of carbon and turn them into carbonic acid gas, and therefore also this part gives little light.

A Chemist's Blow-pipe.

"Now I will take a blow-pipe, and blow a stream of air into the candle flame."

"Oh, look!" exclaimed Harold. "The white part has all gone now. It is nearly all blue."

"How do you explain that, Harold?"

But Harold could not; so Harry told him that

the air blown into the flame had burnt up all the particles of carbon.

Mr. Wood then told the boys to examine the gas-burner that he used for so many of his experiments.

"You see," he said, "there are two holes at the bottom of the burner to let the air in.

"If I close those holes, we get a yellowish flame

Blow-pipe Flame.

which gives us light; but when I open them again, the flame turns blue, and gives very little light.

"Which of these two flames would you think the hotter?"

"I should say the blue one," said Harry.

"And why so?"

"Because all the carbon is burnt up in the blue one," Harry continued, "and so there is more heat."

"Yes, that is right. The blue flame gives more heat; but the yellow one gives more light, because of the little particles of white-hot solid carbon floating about in it."

"Is that why you use the blue flame?" asked Tom.

"Yes, partly so. But you have seen that the blue flame is cleaner, for it does not produce a deposit of carbon on the objects we place in it."

29. COMMON SALT.

"Here is a substance which you all know very well, for you see it every day, but still you may like to know more about it."

Bob thought he knew what the substance was; but, being naturally very inquisitive, he took up a small piece to taste it.

"I thought so," he said; "it is salt."

"Yes, you generally call it salt; but you must remember there are hundreds of compounds called salts; and when we speak in chemistry of this particular one we should either give it its chemical name or call it 'common salt', to distinguish it from the others."

"Then what is its chemical name?" asked Tom.

"If I tell you that it contains the metal sodium and a gas called chlorine, perhaps you will be able to give the chemical name of the salt yourself."

"Oh, I remember!" said Harry. "I have read about it. It is *chloride of sodium.*"

"Yes, you may call it chloride of sodium or sodium

chloride. And now tell me what you know about it besides its taste."

"It will preserve things," said Arthur.

"Quite right. It will preserve animal and vegetable substances; that is, it will prevent them from decaying or decomposing."

"It will dissolve in water, too," said Bob.

"It will; and we generally use the solution of salt for preserving meat, and also for preserving vegetable substances when we require them for museums. The solution of salt is commonly called brine.

"Now, Bob, put a little salt into this water, and stir it round with the glass rod."

Bob did so, and it soon dissolved.

"Now put in some more salt and stir it again; and continue to add more till the water has dissolved as much as it can."

All this was done in a few minutes; and the small quantity of salt that remained solid at the bottom proved that the water could not dissolve any more.

"I will now put the vessel on a stand over a gas burner, till it is very hot."

"I know what will happen then," said Harold. "All the salt at the bottom will dissolve."

"No, you are wrong. Hot water is generally better for dissolving substances than cold water; but in this case it is no better, and you can get

just as strong a solution of common salt with cold water as you can with hot.

"What will happen if I leave this solution of salt in an open vessel for a long time?"

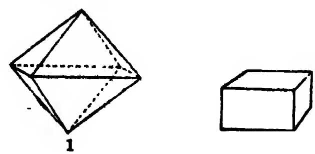
"The water will all dry up," said Harold.

"So it will; but what will become of the salt?"

"It will become solid again."

"Yes. And when a salt passes slowly into the solid state, it forms regular pieces with flat sides called crystals."

"Oh, yes, I remember," said Bob. "We saw some crystals of alum some time ago."



Crystals.—1, Alum. 2, Common Salt

"And do you remember what shape those crystals were, Bob?"

"Yes. They were the shape of a four-sided pyramid."

"Well, you will find that the crystals of common salt are not of that shape. We will set aside this solution in a glass basin, and I will see that it is not touched till you come next week. You will then see what the crystals are like."

"Where does the salt come from?" asked Harry.

"Common salt is found in the sea, where it is dissolved in water, together with several other salts.

"Of course it can be easily obtained by evaporating

the sea-water. This is sometimes done by heating the water in large pans, and sometimes the water is evaporated by the heat of the sun.

"Common table-salt is also obtained by evaporating the water of certain springs called 'brine-springs', which contain large quantities in solution. It is also prepared by purifying rock-salt, which consists chiefly of sodium chloride."

"Are you going to tell us anything about the elements of common salt?" asked Harry.

"Yes; but we cannot come to that this evening. Next Friday I shall talk to you about chlorine."

30. CHLORINE.

"We are going to have chlorine this evening," said Harold, as he carefully examined the apparatus prepared by Mr. Wood. "I suppose it will be prepared from common salt."

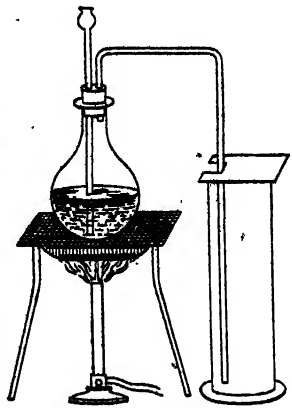
"Yes, common salt," said Mr. Wood, entering the door just at that moment; "and you shall prepare the mixture for the purpose."

He then gave Harold some common salt and some manganese oxide, and told him to mix them well together on a piece of paper.

As Harold was turning over the black oxide, he said to himself, "I think I have seen this stuff before."

"So have I," said Harry, "we used it for making oxygen."

"Yes, we did. It was then mixed with potassium chlorate; but now it will help us to get the chlorine out of the salt."



Apparatus for Preparing and Collecting Chlorine.

As Mr. Wood was saying this, he poured some sulphuric acid into a glass flask, and then he told Harold to throw his mixture into the same flask.

Then the flask was shaken gently to mix the three substances together into a very thin paste; and it was then fitted with a cork and tube, and placed on a stand with a gas-burner below it.

The chlorine gas began to come off at once, and was allowed to pass downward (for it is a very heavy gas) into a gas-jar.

"The flask looks greenish-yellow now," remarked Bob; "and so does the bottom of the gas-jar."

"Of course it does, Bob; for chlorine is a greenish-yellow gas. If you watch the jar carefully you will be able to tell by the colour when it is full."

As soon as it was full it was covered quickly with a glass plate, and a second jar put in its place;

and this was repeated till six jars had been filled with chlorine.

"You saw," said Mr. Wood, "that I covered and changed the jars as quickly as I could, so that very little of the gas got into the air.

"I did that because chlorine has a very powerful and unpleasant smell and because it causes great irritation and coughing when breathed; and that is the reason, too, why I put the flask into the garden as soon as we had obtained all the gas we required."

And even though all this care had been taken, yet the boys said they could smell the gas distinctly; and if the windows had not been wide open all the time they would probably have been very uncomfortable.

"We shall now try some experiments with the gas; and you, Tom, shall stand by me, and take each jar outside the room as soon as we have done with it."

Then the experiments proceeded as follows:—

Into the first jar was placed a lighted candle, and it burned with a very dull and smoky flame, making the jar almost black inside.

Harry couldn't understand how the candle could burn without air, and he was told that the chlorine supported the combustion of the *hydrogen* of the candle, but not of the carbon; and that was the reason why the carbon came off as smoke.

The boys were also told that when the hydrogen

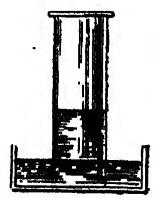
burned in chlorine, the two elements combined, forming a gas called *hydrochloric acid.*

Into the second jar Mr. Wood dropped a strip of blotting-paper that had been moistened with turpentine, and suddenly there was formed a dense cloud of smoke that rose into the air.

The chemical action in this case was exactly the same as in the other, for turpentine, like the candle, contains hydrogen and carbon; but there was no need to light the turpentine, for the heat produced by the chemical action caused it to flame up at once.

A piece of phosphorus was put into the third jar, and it took fire and burned with a feeble flame. As it burned it combined with the chlorine.

Some very thin copper leaf was plunged into the fourth jar. This also burned without applying a light.



Jar of Chlorine inverted in a Tray of Water.

Then a small piece of the metal sodium was heated in a spoon, and plunged into the fifth jar. The sodium burnt, forming white fumes.

The last jar of chlorine was inverted in a shallow vessel of water, and the water rose in the jar, proving that some of the gas must have dissolved in the water.

After all these interesting experiments Mr. Wood sent the boys home, telling them that they would hear something more about chlorine next week.

31. BLEACHING.

"You said you were going to give us some experiments with chlorine to-day," said Harold, "but I don't see the apparatus here with which you made it."

"I made the chlorine this afternoon, Harold, so that I should be quite ready for the experiments as soon as you arrived."

"But where is the chlorine, Mr. Wood?'

"Here it is in this bottle."

"That is not a gas. It is a liquid, like water."

"But do you not see that it is of a greenish-yellow colour."

"Oh, yes! How is that?"

"I have allowed chlorine to bubble into this water for about a quarter of an hour, and a great deal of it has been dissolved. Thus the water has become of the same colour as the gas."

"Does it also smell like chlorine?" asked Bob.

"Try it, Bob."

Then Mr. Wood removed the stopper, and Bob satisfied himself by taking just one sniff, which was quite enough to set him dancing, so strong was the odour of the solution.

"Last Friday I showed you some experiments with the gas, and now I am going to show you what can be done with the solution of the gas."

Some litmus solution was then put into a glass,

and a little of the chlorine water added to it. The colour of the litmus was destroyed at once.

The same thing was done with solutions of logwood, indigo, and other colouring substances obtained from plants; and in every case the colour at once disappeared.

"Will chlorine destroy all colours?" asked Bob.

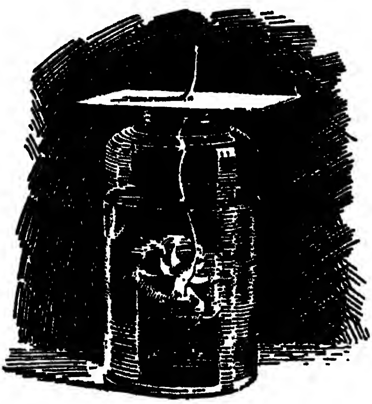
"No, not all colours. The destruction of a colour is called *bleaching*, and chlorine will bleach all the colours obtained from animal and vegetable substances, but not those obtained from minerals."

"Will it bleach a flower?" continued the inquisitive little Bob.

"We will try, Bob. Run out into the garden and get one."

Bob soon returned with a red rose, and was told to drop it into a glass of the solution.

In a short time the colour was seen to fade, and it was not long before the rose was almost completely white.



Flower suspended in a Jar of Chlorine Solution.

"I know you think I am troublesome," said Bob, "but I want to ask one question more. Will the gas bleach as well as the solution?"

"Yes, it will, Bob, providing the substance to be bleached is moist. If you want to bleach by means of the gas a piece of cloth that has been dyed with indigo or any other vegetable or animal colour, you must first moisten the cloth and then hang it in a jar of chlorine; but a flower need not be moistened, for there is already moisture in it."

"Now I think it's my turn to be inquisitive," said Harold. "Will chlorine bleach a negro?"

This funny question of Harold's made all the others laugh heartily, and Mr. Wood himself couldn't help joining in the chorus.

It was some time before they were ready to listen to the answer; but when at last they had recovered from their laughter, Mr. Wood told them that he had never tried the experiment, but thought it extremely improbable that it would bleach living matter.

A piece of printed paper was then passed to Arthur, and he was told to write his name on it with ordinary writing ink, also with a blue pencil, a red pencil, a black-lead pencil, and red ink.

The paper was then put into the chlorine water, and it was found that the writing-inks, both black and red, were entirely bleached, but that the printing-ink and the writing done by the three pencils were not altered.

It was then explained that the latter were mineral colours, and therefore the chlorine had no action on them.

"I have one more experiment for you," said Mr. Wood. "I want to show you how bleaching is done on a large scale, as when ladies' dress materials have to be bleached.

"A large tub is filled with a solution of a white powder called *chloride of lime*, which is sometimes called bleaching-powder, and another tub with weak acid.

"The materials are first rinsed in the former, and then in the latter; and the process is repeated till all the colour is removed."

Two glasses were then filled with these liquids, and Mr. Wood showed the boys how it was done, using for the purpose a piece of cloth that had been dyed with Turkey red.

As the boys were going home that evening, Harold was heard to say that he would get some coloured materials and try to bleach them himself; but Bob said, "Wouldn't it be better to get a negro?"

32. ACIDS.

"We have been using acids for some of our former experiments. Now, I wonder whether any of you can tell me what an acid is?"

"Bob knows what an acid tablet is," said Harold, laughing. "He is sucking one now."

"Let me have one, Bob, and we will try an experiment with it."

Bob passed over his little packet of luxuries, thinking that Mr. Wood was going to perform the same experiment as that in which he was engaged.

But he was greatly mistaken, for the tablet was put into a glass of water, and stirred about until a little of it was dissolved.

Some solution of litmus was then poured into the glass and it immediately turned red.

"Now you see why it is called an *acid* tablet, Bob. It really contains a solid acid, mixed with sugar.

"You have been told on former occasions, that acids turn litmus red; but we are now going to learn something more about them.

"Here is a purple liquid, prepared by pouring boiling water on flowers of that colour. I will add to it two or three drops of a liquid acid, and you notice that the mixture turns red as the litmus did.

"Most blue colours obtained from plants are turned red by acids. I will give you another example."

Mr. Wood then took a bunch of violets, and dipped them in an acid, and soon they all went quite red.

"Are there many solid acids?" asked Harry.

"Yes, there are many of them; and some, such as citric, tartaric, and oxalic acids, are well known to nearly everybody.

"There are also many liquid acids, some of which we have already used; and some acids are gases at ordinary temperatures.

"Do you remember how we prepared hydrogen some time ago?"

"I think I remember," said Harry. "You put some sulphuric acid in a bottle containing zinc."

"Yes, and when the diluted sulphuric acid was poured on zinc, it exchanged its hydrogen for the metal, and so formed a substance called *zinc sulphate.*"

"Is zinc sulphate an acid?" asked Tom.

"No, it is a salt. All acids form salts when they act on certain substances."

Then Harold said, "The other day, when my father was eating some fruit, he said it was very acid. What did he mean by that?"

"He meant that it was very sour and had a sharp taste. Most of the common acids have such a taste, and so we say that substances are acid when they are sharp like Bob's tablets."

"May I taste one of the acids?" said Harold.

"You have done so many a time, Harold. Vinegar is an acid substance, and the unripe fruits that you have eaten at different times all had acids dissolved in their juices."

"Yes, but I should like to taste one of *your* acids," said Harold.

"Well, you must remember that many of the

acids are very poisonous; but here is one that you may taste if I make it very weak with water."

Mr. Wood put a few drops of hydrochloric acid into a glass, and filled it up with water, and allowed Harold to taste it.

Harold noticed that it was rather sharp, but Mr. Wood cautioned him that he was never to taste any chemical unless it was given to him by someone who was thoroughly acquainted with its properties.

He knew that Harold, like Bob, was inquisitive; and so he cautioned the boys that they were to regard all chemicals as poisons until they became well acquainted with them.

33. OIL OF VITRIOL.

"Last week I told you the chief properties of acids, and now I shall tell you something about the most important of all these substances. It is called oil of vitriol, but its chemical name is *sulphuric acid.*"

"Are all oils acids?" asked Tom.

"No, none of the oils are acids, and the substance commonly known as oil of vitriol is not really an oil at all; but it has the appearance of an oil when you shake it or pour it from one vessel into another."

Mr. Wood then allowed the boys to shake the

bottle of sulphuric acid gently, and they noticed that the liquid did not move so readily as water does.

"It seems much heavier than water," remarked Harry.

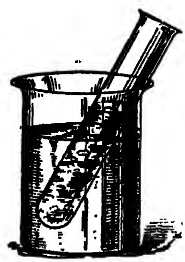
"Yes, Harry; it is nearly twice as heavy as water. I will now show you that it is an acid."

A few drops were then poured into a glass of water, and stirred round with a glass rod.

The boys were allowed to taste this very weak solution; and some litmus solution which was added to it turned red at once.

"Oil of vitriol must be a very strong acid," said Harold, "for a few drops will make a whole glass of water sour, and even when weakened with so much water it turns litmus red."

"Yes, it is certainly a very strong acid, and now we will see what it can do when it has not been weakened by so much water."



Alcohol boiled by means of Sulphuric Acid and Water.

A little water was then put into a glass, and about twice as much acid was slowly poured into it, the mixture being stirred all the time.

"It is getting hot, isn't it?" said Harold.

"Yes, it is very hot now. Both the liquids were cold at first, but by being mixed much heat has been produced. Just look at this experiment."

Mr. Wood then put some alcohol into a test-tube and placed the test-tube in the mixture of sulphuric acid and water; and the heat was sufficient to make the alcohol boil in a very short time.

The tube of boiling alcohol was then removed, and some pieces of loaf-sugar were dropped into the glass.

Sugar charred by Sulphuric Acid

Then the sugar turned black and began to swell up. In a short time it had swollen so much that it rose up above the top of the glass and jets of steam began to shoot out from it.

Harold was much amused at this, and said it reminded him of a volcanic eruption. As they watched it, it turned black, and Bob remarked that the black stuff looked just like charcoal.

"And so it is charcoal," said Mr. Wood. "The experiment is certainly a very amusing one, but there is something to be learnt from it. I will explain it to you.

"When I mixed the sulphuric acid with water, you noticed that heat was produced. This was a proof that a strong chemical action was going on between the two liquids.

"Now sugar contains carbon, hydrogen, and oxygen; and as hydrogen and oxygen are the two

elements of water, we may regard sugar as being composed of carbon and water.

"So when the sugar was put into the acid, the acid combined with the water of the sugar, thus leaving the carbon by itself in the form of a black mass of charcoal.

"Sulphuric acid will act in this manner on most animal and vegetable substances, all of which contain carbon, hydrogen, and oxygen."

This was illustrated by two other experiments.

A piece of stick was dipped into the strong acid, and soon became black, looking as if it had been burnt.

Also, a little of the acid was shaken up with some oil in a test-tube, and the oil was blackened in the same way.

"And now, you see", said Mr. Wood, "why a bottle containing this acid should never be stopped with a cork, for it would at once attack the cork and eat it away."

"Do all strong acids act in this way?" asked Harry.

"No, Harry. I have already told you the properties which belong to *all* acids, but our last few experiments show you how we are able to distinguish sulphuric acid from other strong acids."

Then little Bob, who considered that he had gained some useful knowledge, said, "If anyone were to give me a bottle containing an acid, I

think I could soon tell him whether it was sulphuric or not."

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34. ALKALIES.

On the following Friday Tom and his father had made preparations for the evening's experiments a little earlier than usual, and all being ready, some time before the boys were expected, Tom went down the road to meet them.

When they saw Tom in the distance, Harold ran up to him, and anxiously inquired what the lesson was to be about.

"I hope we are going to hear more about oil of vitriol," he said, "for I should so much like to see that sugar experiment again."

"We are not going to have that again," said Tom; "but father says he will give us a lesson on *alkalies.*"

"Alkalies!" exclaimed Harold, as the other boys approached them; "what are they?"

"I don't know any more than you do," replied Tom; "but I suppose we shall learn what they are soon."

And so they walked on, chatting about the experiments, till at last they found themselves in Mr. Wood's study; and before their teacher had time to announce his subject, Harold repeated his question about alkalies.

"You are in a great hurry to begin, Harold; but I will show you an experiment before answering your question, and perhaps you will then be able to tell *me* what an alkali is."

Some litmus solution was then poured into a glass, and turned red by adding one drop of acid. Then Mr. Wood added a substance, which he said was a solution of an alkali, and the litmus at once turned blue again.

"Now," said he, "can you tell me what an alkali is?"

"It is a substance which destroys acids," said Harry.

"Well, you are nearly right, Harry. In fact, your meaning may be quite correct. What do you mean by the word 'destroyed'?"

"You told us that substances could *not* be destroyed," remarked Tom.

"That is just what *I* was thinking about," said Mr. Wood.

"Oh, I don't mean that the *elements* of acids are destroyed by alkalies, but that their *properties* are destroyed," said Harry.

"That's nearer the mark, Harry. An alkali is a substance which will destroy the properties of an acid, and so you see that alkalies and acids are two opposites."

Mr. Wood then added one drop of the acid to the same solution of litmus, which had been turned

first red, and then blue. But no change took place.

He went on adding acid, drop by drop, very slowly, and at last the litmus turned red again. And then he continued to add alkali and acid in turn, thus changing the colour of the litmus from red to blue, and blue to red, several times.

"Now, you see," he said, "that an alkali can destroy the properties of an acid, and an acid can destroy the properties of an alkali."

"But why did not the colour of the solution change from blue to red when you added only one drop of acid?" asked Tom.

"Simply because that quantity of acid was not sufficient to destroy the properties of *all* the alkali that was present."

"What is the name of the alkali?" asked Harry.

"I used a weak solution of an alkali called *caustic soda.* Here is the solid caustic soda, in the form of sticks."

"Harold, dip your fingers into this weak solution of caustic soda, and tell us what you notice."

Harold did so, and found that the solution made his fingers feel smooth and slippery, just as they do when they have been soaped.

"That is one of the properties of the chief alkalies, and they also have a taste resembling that of soap."

"Are there many alkalies?" asked Tom.

"There are many substances that possess alkaline properties, but the three most powerful alkalies are *caustic soda*, which we have just been using, *caustic potash*, and *ammonia*."

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35. WASHING SODA.

"What is the subject for this evening, Mr. Wood?" asked Harold.

"I am going to give you a lesson on a well-known solid substance—common washing soda.

"First, I will put some in water, and stir it with a glass rod. You see that it quickly disappears, and therefore we say it is very soluble in water, and the mixture is called a solution of soda."

Mr. Wood then put some litmus solution into another glass, and turned it red by adding to it a drop of acid.

He then poured some of the solution of soda into it, and the colour was at once changed to blue, proving that washing soda is an alkali.

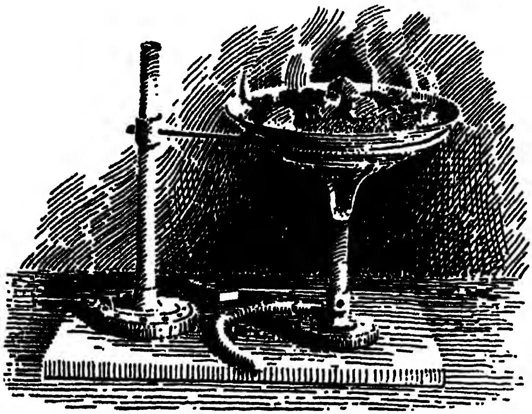
Then followed another experiment. Some of the soda was placed in a basin, and the basin was heated over a gas-burner.

At first the soda melted. Then it boiled up, and a quantity of vapour was driven off; and at last it became quite dry and white like chalk.

While the liquid was boiling, Bob asked what

vapour it was that rose from it, and was told that he would soon find out if he held a cold basin just over the hot one.

He did so, and found that it was water-vapour, for the cold basin became very wet with water.



Heating Soda to drive off the Water.

"From this experiment, boys," said Mr. Wood, "you see that washing soda contains a large quantity of water, which is easily driven off by heat, and that a white chalky-looking substance is left.

"This substance has just the same properties as it had before it was heated. It is still washing soda, but changed in appearance.

"At first it was in glassy transparent pieces with flat sides, and such pieces are called crystals of soda. But now it has lost its glassy appearance, and has no regular shape.

"If I were to add to this just as much water as was driven off by the heat, I could, in time, get it all in the form of crystals again.

"And so you see that washing soda can exist in two different forms, but that it cannot be in crystals unless water is present. The water that is necessary for this purpose is, therefore, called *water of crystallization.*"

After giving this explanation, Mr. Wood showed the boys another experiment.

He put some washing soda into a test-tube, and then added some acid to it. Then it began to bubble up just like boiling water.

Harold asked if it was hot, but when it was passed over for him to feel it, he found that it was quite cold. The acid was simply driving off a gas from it.

"This gas is a heavy one, so that I can easily pour some of it into another tube," said their teacher. And he did this, but was very careful not to allow any of the liquid to pass with it.

"I didn't see any go in," said Harold.

"No, of course not, for it is an invisible gas; but I can easily prove that it is there, and also show you what gas it is."

A little lime-water was then put into the tube, and shaken up with the gas, which at once turned milky.

"Oh, now I know what gas it is! It is carbonic acid gas."

"Yes; you are right, Harold. Can you remember another experiment you have seen, something like this one?"

"I do," said Harry. "You obtained the same gas by adding an acid to chalk."

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36. SALTPETRE.

"To-night, boys, we are going to have a change; for you shall do all the experiments yourselves."

"Oh, how jolly!" said Harold "I hope I shall have a good one."

"Here are your instructions for the start:—Harry, you write your name on this sheet of paper. Use this fine brush, which you will dip into this liquid that looks like water."

"That's a funny experiment," said Harold. "I hope I shall get a better one than that. You won't be able to see the name when it is dry."

Harry, however, took no notice of this remark, but went on with his experiment.

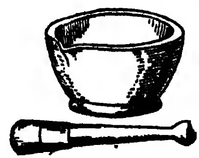
"Now, Tom, I want you to grind some of these crystals of saltpetre to a fine powder in the mortar, and then shake it up with water in a test-tube, a little at a time, till the water will dissolve no more."

"What shall I do?" said Harold, who was anxious to have his work set.

"You shall crush this piece of charcoal to a fine

powder; and, Bob, you shall take a little of the liquid which Harry is using for his writing, and evaporate it in a basin over the gas-burner.

"Now, Arthur, it is your turn. You shall heat a little saltpetre in a test-tube and notice what changes take place."


Mortar and Pestle for Grinding.

Thus all the boys were busily engaged for a time; but one by one they had done the work set them, and asked for further instructions.

When Harry had finished his writing, he was told to hold it before the fire till it was quite dry.

"There," said Harold. "I told you that you would not be able to see the writing when it was dry."

But Mr. Wood showed them that if they looked very carefully at the paper in a good light, they could just see very small glistening crystals where the liquid had been.

"The water which Harry used had some saltpetre dissolved in it; and when the water evaporated, it left behind very small crystals of the salt on the paper," said Mr. Wood.

Harry was then told to touch the paper with a spark, just where these little crystals were visible; and when he did so, the paper began to smoulder away with a slight fizzing sound, but only just where the brush had touched it.

And so, as the spark travelled onward over the paper, it traced the word "Harry" as it went.

"That's a fine experiment after all," said Harold. "I wish you would explain it to us."

"The *saltpetre*, or *nitre*, as it is sometimes called," said Mr. Wood, "contains oxygen. And when it is

The smouldering Paper.

heated, oxygen is driven off. And you all know that oxygen is a supporter of combustion. And so the paper was burnt only where the saltpetre had been placed."

"I am heating some nitre in a test-tube," said Arthur. "Will any oxygen come off from this?"

"Yes. At first the crystals melted, but now you see that it is bubbling; and if you put into the test-tube a chip with a spark on the end, it will burst into a flame."

Arthur did so, and thus proved that saltpetre contains oxygen.

"I have made my solution of saltpetre," said Tom. "The water will not dissolve any more, for this little bit of the powder at the bottom of the tube will not disappear."

"Now make it hot over the gas, Tom, and then it will dissolve."

Tom did this, and then added more, which also dissolved. He repeated this several times, and found that the hot water would dissolve much more saltpetre than the cold water.

He was then told to let it cool; and, as it cooled, little slender crystals of saltpetre began to form in the tube.

The boys then turned their attention to Bob's experiment. The water had all boiled away, and there was some saltpetre left in the basin.

This saltpetre, you will remember, was obtained from the liquid which Harry had used for his writing.

"What shall I do with my powdered charcoal?" said Harold.

"Grind up this saltpetre with it till the whole is very fine and well mixed."

This did not take long, and, when it was done, Harold was told to put the black powder in a little heap on a piece of slate, and then light it.

He made the little heap just the shape of a volcano and lighted it on the top; and it burned away beautifully, throwing off a number of little bright sparks.

"That's just like gunpowder," he said, "only it burns more slowly."

"Gunpowder contains both saltpetre and charcoal, Harold; but I asked you to do this experiment in order to show us how readily the charcoal burns in the oxygen that is driven off from saltpetre when heated."

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37. SULPHUR.

"This evening I am going to tell you something about sulphur—a substance that has already been mentioned in some of our former lessons. I should first like to see what you remember about it."

"I don't forget sulphur," said Harold. "I tried my first chemical experiment with it. You showed us how to make crystals of sulphur, but when I tried to do it at home, the smell was so strong that everybody had to go out of the house."

The boys all laughed at Harold's misfortune, even though they had heard of it before; but he had never told Mr. Wood of his failure.

"And didn't you get any crystals after all, Harold?"

"No, I didn't. The sulphur all went thick and black, and then it caught fire, so that I had to take it out into the garden. We were all nearly suffocated by the gas given off, and I got into trouble for spoiling the saucepan."

Mr. Wood could not help laughing, too, when he heard Harold relate his sad tale, but he gave him a little advice to guide him in his future attempts.

"You should not attempt chemical experiments, Harold, without knowing something of the nature of the materials you use, unless you are very careful to follow exactly the methods you have seen successfully employed by others.

"I used a clay crucible; you used an iron saucepan. Now sulphur does not change clay, but it combines with iron, as I have already proved to you, forming iron sulphide; and a saucepan made of iron sulphide is not of much use.

"Again, I melted the sulphur very gradually, over a gas flame, and did not allow it to get thick and black; but you put it over a hot fire and heated it fiercely.

"Well, you have all just been reminded of two things we have learnt about sulphur:—First, the formation of crystals by melting it and then allowing it to cool; and, second, the preparation of iron sulphide by heating iron and sulphur together. Can you tell me anything else about it?"

"It is an element, and also a non-metal," said Harry.

"Quite right; and now I will give you some more information about this interesting substance.

"Many of the elements are never found free or uncombined in nature, but are always met with in

compounds from which they have afterwards to be separated. But sulphur is found in a free state in many countries, more particularly in parts of Italy and other volcanic regions.

"In this form it is a yellow crystalline substance, mixed, but not combined, with more or less rocky matter, and is known as native sulphur.

"Sulphur also occurs in very large quantities combined with other elements. We get much of our sulphur from a mineral called *iron pyrites.* Sulphur is also found largely in combination with copper, lead, silver, zinc, and other metals. Alabaster, a beautiful crystalline rock, much used for making ornaments, contains sulphur."

Mr. Wood now showed the boys some native sulphur, and various minerals containing sulphur. He also showed them a number of the different forms of sulphur, which, although not alike in appearance, were all, he said, pure sulphur.

One was roll sulphur, in long thick sticks, which were made by melting sulphur and running it into moulds.

Another was flowers of sulphur, in the form of a very fine powder. It had not been powdered in a mortar, but was made by boiling sulphur, and then condensing the vapour given off.

A third was in the form of long and slender needle-like crystals; but these the boys knew, as they had seen them made.

There were also eight-sided crystals, shorter and thicker than the others; and, lastly, there was a darker brownish kind of sulphur, which would bend and stretch like india-rubber.

Mr. Wood concluded with an experiment. Two pieces of roll sulphur were put into separate bottles, one containing water, and the other a liquid called *carbon disulphide.*

The water did not appear to dissolve the sulphur at all, but the piece in carbon disulphide rapidly became smaller. However, the two bottles were to be set aside till the following week, when both the liquids would be tested.

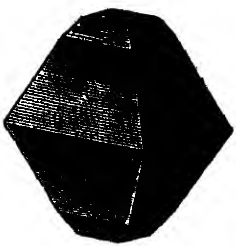
38. MORE ABOUT SULPHUR.

When the boys met on the following Friday, Mr. Wood placed before them the two bottles containing sulphur and a liquid. The sulphur which had been put into carbon disulphide had entirely dissolved, but that in the water did not appear to be any smaller.

Mr. Wood then took two watch-glasses, into one of which he put a single drop of the liquid from the first bottle, and into the other a drop from the second. He allowed both to dry up, and when examined it was found that the water had left no mark, but the carbon disulphide had left a little

round patch of very small glistening crystals of sulphur. It was thus evident that the water had not, and the disulphide had, dissolved some of the sulphur.

Another very interesting experiment was now performed. About an ounce of sulphur was placed in a porcelain crucible, and heated *very slowly* over a gas-burner.


Crystal of Sulphur.

Almost immediately the sulphur began to melt, producing a very pale yellow liquid; but it was some time before all had melted.

When, at last, all the sulphur had melted, it began slowly to turn darker, becoming of a reddish-brown colour, and soon after it began to thicken at the bottom like syrup.

Then the colour grew very dark—almost black, and the whole of the sulphur became so thick that Mr. Wood held the crucible upside down for a short time without spilling any of it.

"What chemical changes have taken place to cause all these different appearances?" asked Harry.

"No changes at all have occurred. The sulphur is as pure now as at first; and the experiment was shown you, to let you see that there may be changes in appearance and properties without any change in composition."

Mr. Wood now poured some of the thick, syrupy sulphur into a vessel of cold water, in order to cool it rapidly. It became solid as it fell through the water; but when taken out it was quite soft and plastic like putty.

"This is called plastic sulphur," he said. "I showed you a similar piece of it last Friday, which I have still beside me. Here it is, but you see it has changed.

"When you saw it before it was freshly prepared, and was like the piece we have just made. But by standing it has returned to its pale-yellow colour, and is so brittle that the slightest attempt to bend it causes it to snap.

"So you see, plastic sulphur does not retain its plasticity very long."

The remainder of the sulphur in the crucible was now heated still more, for there were further changes to be observed.

It still remained dark in colour, but became thinner than before, so that it could be easily poured out.

Then, after a few minutes, it began to boil, and a dark, reddish vapour came off; but this vapour condensed as soon as it came into contact with the cool air, forming a yellowish dust, which, Mr. Wood told them, was flowers of sulphur.

This went on for a short time, and then, suddenly, the sulphur caught fire, burning with a pale-blue flame, and giving off a powerful suffocating odour.

"We must not breathe much of this," said Mr. Wood; and Harold, thinking he was working for the good of all, began to puff away furiously at the burning sulphur to blow it out.

But the harder he puffed the brighter it burned; and then Mr. Wood said, "Don't you know, Harold, that sulphur cannot burn without air." At the same time he placed a cover on the crucible, and the combustion ceased at once.

"Now, Harold," he continued, "if you are going to perform any other experiments with sulphur, remember this: If you want crystals of sulphur, let the sulphur only just melt, and then let it cool slowly; but if you want to make plastic sulphur, you must continue to apply heat till the sulphur becomes so thick that it runs very slowly indeed, and then pour it into cold water to cool quickly.

In either case, of course, the sulphur must not be allowed to catch fire, for then it combines with oxygen of the air, and forms a gas, which is not a variety of sulphur, but a compound containing it."

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39. CLAY.

"Here is a piece of granite, boys. Examine it, and tell me what you observe," said Mr. Wood.

"I can see a glassy-looking substance," said Harold. "What is that?"

"It is *quartz*," replied Mr. Wood.

"What is this silvery-looking substance, in little flat pieces?" asked Harry.

"That is *mica*—a transparent substance that is often used as a substitute for glass, especially for lamp chimneys, and for other purposes in which a transparent material that will withstand much heat is required."

Thin Slice of Granite as seen under the microscope. It is composed of the minerals quartz, felspar, and mica.

"There is another substance in the granite," said Tom. "It is white, not glassy like the quartz, and it seems to form a large portion of the rock."

"That is called *felspar*," said Mr. Wood, "and it is that which I want you to notice more particularly.

"In this other piece of granite you will see that the felspar is softer; so soft, in fact, that you can almost crumble it between your finger and thumb.

"Felspar contains *silica*, *potash*, and *alumina*.

"When granite has been exposed for ages to the air, or to water containing carbonic-acid gas, the potash contained in the felspar is dissolved out, and then the remaining parts of the felspar—the silica and alumina—combine together into a com-

pound called *silicate of alumina*. This is gradually washed out, forming a kind of white clay.

"This clay is called *kaolin*, or china clay, and is the material used for making our cups and saucers and other 'china goods'.

"Here is some of this clay in the form of a white and dry powder. You may not think that it resembles clay all; but this piece that I have here, which has been mixed with water, can be moulded into any form, just like ordinary clay."

"We have some clay under the soil of our garden," said Arthur, "but it is of a yellowish colour."

"Yes, clays are of all colours, but china clay is pure silicate of alumina, while the ordinary clays, of various colours, consist of this compound mingled with different impurities. In fact, the colours are due to the impurities present.

"Now, Arthur, I want you to work up some clay into the form of a cup, and then try whether it will hold water."

Arthur was not long making the cup, and when he had finished it he filled it with water, and the water did not run through.

"The water would run through in time," said Mr. Wood, "but very slowly; and when the clay is baked it is still more porous. This is the case with an ordinary flower-pot which is made of baked clay.

"Cups and jugs, and all earthenware and china vessels which are intended to contain liquids, are

covered with a glaze, which is melted on the surface of the clay; and this prevents the liquids from passing through.

"I will now show you some *aluminium* — the metal of which clay is a silicate. Here is a piece of it, and you see that it is much like silver in appearance.

"It is one of the most abundant of the metals; but, as it is not very easy to extract it from the clay, it is not yet used very extensively.

"It is much cheaper now than it was a few years ago, as improved methods of producing it have lately been discovered; and it is probable that, before long, it will be obtained cheaply, and we shall find it worked up into various kinds of articles that are at present made of other metals.

"Thimbles, pencil-cases, and numerous other articles made of aluminium can be obtained at a low price; and the metal is already being used for the manufacture of boats and various large instruments."

Then the inquisitive little Bob, who had been examining the piece of aluminium, remarked that it was very light, and the others were then asked to try its weight by holding it in their hands.

"Now," said Mr. Wood, "you will perhaps be able to tell me one reason why aluminium is likely to take the place of certain commoner metals?"

"I should think it would be very useful for

making machinery," said Harry; "that is, if it is strong enough."

"It is a very strong metal; and being also very light, it will undoubtedly be used largely in the future for the manufacture of engines and other large things in which weight has to be considered.

"It has also another advantage over iron, for it does not rust on exposure to moist air. Further, its usefulness is increased by other valuable properties; for it can be readily beaten into thin sheets or into any desired form, and it can also be drawn out into wires.

"In one respect, however, it is at a great disadvantage compared with iron. No means has yet been discovered of welding two pieces of aluminium together, and to make a joint it is necessary to rivet."

Then Arthur produced the pencil-case which his father had given him on his last birthday.

"They call this *aluminium gold,*" he said; "but it is not like your aluminium. What is it, please?"

"Aluminium gold," said Mr. Wood, "really contains no gold at all, but is a mixture of aluminium and copper. It has the appearance of gold, and is almost as good for ornamental purposes, as it does not tarnish."

PART III.—COMMON METALS.

40. MERCURY.

"You remember, boys, that several weeks since I showed you some mercury or quicksilver, which is the only liquid metal. Well, here it is again; and this evening we are going to learn something about it.

"Nearly all the mercury we use is obtained from a mineral substance called *cinnabar*, which contains the metal combined with sulphur; but sometimes the metal is found free, that is, not combined with anything, but just as you see it in this bottle.

"You may all lift the bottle, and tell me whether you think the mercury is heavier or lighter than water."

Harold was the first to do this, and he found it so hard to lift that he thought the bottle had stuck to the table.

"It is very much heavier than water," he said; "and, I should think, much heavier than iron, too."

"You are right, Harold. It is much heavier than either water or iron. This bottle will hold only six ounces of water, but it now contains quite five pounds of mercury.

"Bob, put some water into this tall glass, and then pour in about a half of the mercury."

When this was done, they noticed that the mercury all fell heavily to the bottom, and the water floated on the top of it.

An Iron Ball floating on Mercury.

Harry was then told to drop a ball of iron, which Mr. Wood had procured for the purpose, into the same glass; and, strange to say, the iron fell through the water, and then rested on the top of the mercury just as a piece of wood rests on water.

"Now you see that iron is lighter than mercury, for a substance will only float on a liquid that is heavier than itself."

Mr. Wood then called the boys' attention to some mercury in a test-tube that was standing in a vessel of boiling water.

"You see," he said, "that the water is boiling, but the mercury is not; that shows you that water boils at a lower temperature than mercury."

"I should like to see mercury boil," said Harold.

"Well, you shall soon see that," replied Mr. Wood, who then removed the test-tube from the boiling water, and held it in the gas-burner.

In less than a minute the mercury was boiling vigorously, and a vapour was given off, which condensed on the sides of the tube, forming little round drops that rolled down again as they became larger.

"How bright the mercury is!" said Bob. "You can see yourself in it quite clearly."

"Yes, it is very bright, Bob; and does not tarnish when exposed to air as many metals do."

"Then it does not combine with oxygen, as iron does?" said Harry.

"Not without heat, Harry. If it is heated to a temperature a little below the boiling point, and kept at that temperature for a long time, then it combines with oxygen very slowly, and forms the red oxide of mercury, which we have already used for one of our experiments."

Mr. Wood then put a very little drop of mercury into a test-tube, and told Arthur to find out whether it was soluble in water.

Arthur added water to it, and shook the two liquids together for a time; but the drop of mercury did not become any smaller, so he knew that none of it had dissolved.

"Can mercury be dissolved at all?" asked Harold.

"We will try, Harold."

Most of the water was then poured out of the test-tube, leaving the heavy mercury at the bottom; and a little nitric acid was added.

Almost immediately little bubbles of gas were seen to rise. Soon they came off rapidly, with a hissing noise, and the mercury became gradually smaller and smaller, till at last it had all disappeared.

"We will have one more experiment," said Mr. Wood, "and Arthur shall perform this one. Take this piece of tin-foil, and bend it into the form of a little cup."

This was soon done, and then Arthur was told to pour a drop of mercury into it.

When he had done as he was told, the mercury soon began to creep up the sides of the little cup; and, while Arthur was showing this to the others, down fell the mercury through the tin cup, leaving a hole in the bottom of it.

"How do you explain that, Arthur?"

But Arthur couldn't make it out at all. Harry explained it. He said that the mercury must have dissolved the tin.

"Yes, that is the explanation. Mercury will dissolve many of the metals in this way, just as water will dissolve sugar and many other substances. This mixture of mercury and another metal is called an *amalgam*."

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41. LEAD.

"We are going to talk about another metal this evening. In fact, we shall deal with several of the

commonest metals, taking one each evening for a good many weeks.

"This is the one for the present lesson," continued Mr. Wood, holding up a piece of metal for the boys to see. "I wonder whether you can tell me what it is."

Harold took it up, looked at it carefully, cut off a little piece with his penknife, and then scratched it with his thumb-nail.

"I know what it is," he said, putting down the piece of metal for the others to examine.

"Well, what is it, Harold? and what are the properties by which you know it?"

"It is lead," replied Harold, "and I know it by its bluish colour and its weight. It is very soft, too, for I can scratch it with my nail."

"That is right, Harold. And now, Arthur, here is a piece of iron of about the same size as the lead, and I want you to find out which is the heavier."

Arthur then took the lead in one hand, and the iron in the other; and noticed at once that the lead was much heavier than the iron.

"Is it as heavy as mercury?" asked Tom.

"No, not as heavy as mercury, Tom. Mercury weighs more than thirteen times as much as the same volume of water, and lead about eleven times as much.

"Now, can you tell me why lead is used so much for gas and water pipes?"

"Because it does not rust," said Bob.

"Yes, that is one reason why it is better than iron; but there is another. It is because lead bends so easily that it can be made into any shape or turned round ever so many corners without fear of its breaking."

"What heavy substance is this?" asked Harry, as he picked up a large lump of a shining crystalline mineral. "It looks something like lead, but it is hard."

"Let me see it," said Harold, eager again to display his knowledge of things.

After looking carefully at the curious substance, and observing that it was very hard and very brittle, he said, "I give it up. It is not at all like any metal I've seen before."

Mr. Wood smiled at Harold's remark, and told him it was not a metal at all, for it was a compound mineral substance, and not an element.

"It is called *galena*," he said, "and consists of lead and sulphur combined together. It is the ore from which we get most of our lead.

"You see that it is easily crushed to a powder, but lead is simply flattened out when you beat it."

"What are these other substances?" asked Harold, pointing to a row of bottles containing powders of different colours.

"These are all compounds containing lead. This first one is *white lead*, and is used very largely for making paint.

"The next is called *sugar of lead.* You see it is a crystalline substance, and looks something like a fine white sugar. It is very poisonous.

"The other two bottles contain oxides of lead—one a yellowish oxide called *litharge,* and the other

Galena and Galena Crystals.

a red oxide known as *red lead.* These two are both used in making paints and cements, and they can be formed by exposing melted lead to the air.

"The substance called 'black lead', you remember, contains no lead at all. It is a variety of carbon."

Mr. Wood then put a piece of lead in an iron spoon, and showed the boys how easily it would melt over the gas-burner.

"You have a box of colours, Tom," said Mr. Wood.

"Yes, father," replied Tom.

"Run and fetch it, Tom; for I want to speak to you about one of the colours."

When Tom returned, Mr. Wood asked him to take out the cake of chrome yellow.

"Now, would you like to see how that colour is made?"

"Oh, yes!" said all the boys at once. "Do show us."

Mr. Wood then dissolved some sugar of lead in a test-tube of water, and a substance called *potassium chromate* in another test-tube.

As soon as both had completely dissolved, one liquid was added to the other, and a bright-yellow powder was at once formed.

"This powder is chrome yellow," he said, "and if we let it stand till it all settles to the bottom, and then pour off the water, the remaining solid makes a capital yellow paint."

42. SILVER.

"What is the metal this evening?" asked Harold, before Mr. Wood had had an opportunity of naming his subject.

"Silver, this time, Harold," he replied.

"Oh, that's a good one!" said Harold; "I wish I had plenty of it."

"I suppose you do, Harold. We all should like

to have plenty of silver and gold, but you must remember that some of the commoner metals, such as iron and lead, are of far more use to us than some of the rarer and more beautiful ones.

"Silver and gold are both used very largely for ornamental purposes, because they keep their appearance well; but silver tarnishes when it is exposed to air, particularly in rooms where gas is burning; for the fumes of the gas contain small quantities of sulphur, and some of this combines with the silver.

"Now, here is a piece of pure silver. Look at it, and tell me what you learn about it."

"May I cut it?" said Harold.

"Yes, you may if you like."

"It is not very hard," said Harold, after trying it with the edge of his knife, "but it is much harder than lead. And it is not so heavy as lead," he added.

"It is certainly harder than lead—much harder; but there is not much difference in their weights. It seems much lighter to you because the piece of silver you have is so much smaller than the lead you examined last time. I told you that lead is about eleven times the weight of the same volume of water, and silver is ten-and-a-half times the weight.

"Silver plate and silver coins are not made of pure silver. A small quantity of copper is always

mixed with the metal, in order to render it more durable.

"Now, Harold, hold one end of this piece of silver wire in the gas flame for a minute or two."

"Ah! I see what your trick is," said Harold to himself; for he remembered how they all laughed at him when he burnt his fingers by trying the same experiment with copper wire.

Harold did not mean to be a laughing-stock this time, so he passed the wire over to Bob, who was willing to risk the result.

But Bob could not hold it in the flame long. The heat soon travelled through the short piece of wire, and he was obliged to throw it down.

"Well, Bob, what does that teach you?"

"Silver is a good conductor of heat," replied Bob, promptly.

"Yes, it is the best of all the conductors of heat," said Mr. Wood; "better even than copper.

"Now look at this piece of ore. You see it is something like galena. It contains silver in combination with sulphur, and is one of the chief ores of silver. It is called *silver-glance.*

"Silver is also found pure in nature, and lead ore often contains so much silver that it pays to extract it.

"There are two other properties of silver that we must mention. It can be beaten out into very thin sheets, much thinner than ordinary writing-paper;

and it can be drawn out into extremely thin wire without breaking.

"Now I have an interesting experiment to show you," continued Mr. Wood; and when he took a sixpence out of his pocket and put it into a test-tube, the boys wondered what he was going to do.

Some nitric acid was then poured into the tube, and bubbles of a reddish-brown gas came off rapidly, and the acid turned green.

This went on for some minutes, and at last the sixpence had quite disappeared, the whole of it having been dissolved.

"What a shame!" exclaimed Harold, who began to reckon up all the jam-tarts and chocolate-creams that might have been purchased with the silver coin.

But Mr. Wood continued his experiment, taking no notice for the present of Harold's disappointment.

He put the test-tube into a glass of cold water, for heat had been produced by the chemical action; and when it was quite cold, there were crystals of a colourless salt at the bottom of the green liquid.

"This salt," he said, "is *silver nitrate*, and together with some more of the same substance, which still remains dissolved in the liquid, it is worth as much as the coin I used; and I can assure you, Harold, that I don't intend to waste it, for it will prove useful to me one day.

"One thing more," he added; "the green colour of the liquid is due to the presence of copper."

And to prove this, he put the blade of a knife into the liquid for a moment, and it became quickly covered with a thin layer of copper.

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43. COPPER.

"I have not yet given you a lesson on copper, but we have used copper for two or three of our experiments in former lessons. So, before I begin to tell you anything about it this evening, I must first see what you already know."

"I shall not forget that copper is a good conductor of heat," said Harold.

"Nor shall I forget how copper covered the blade of my knife, when I dipped it in the solution," said Bob; "for there are still little red patches of the metal on it."

"Now, we will examine a piece of the metal, and see what more we can learn about it."

Harold at once commenced the examination of the copper after his usual manner; first bending, and then scratching and cutting it with his penknife.

"I shouldn't call it a very hard metal," he said, before any of the others had had a chance of handling it at all. "See how easily my knife scratches it, and I can also cut off little chips of the copper."

"It seems to be much softer than this penny,"

he continued, after repeating his scratchings and cuttings on his only piece of money. "How is that, Mr. Wood?"

"Well, a penny is not all copper," was the reply.

"Then why do we call pence coppers?" asked the inquisitive boy.

"Because a penny contains more copper than any other metal. It consists of ninety-five parts of copper, four of tin, and one of zinc; and this mixture of metals is called *bronze.*"

"Then, if a penny contains so much copper, why not make it entirely of copper?" asked Tom.

"Harold has already answered that question, by showing you that bronze is harder, and therefore more durable than pure copper.

"Brass is another example of a mixture of metals containing copper. It contains copper and zinc only, and the zinc not only gives it a lighter yellowish colour, but adds to the hardness of the metal.

"Now I want you to examine these minerals, all of which contain copper. The first is called *native copper*, and is really the metal found in a pure state. If I scrape off some of the dull outer part with my knife, you can see at once that it is just like this piece of pure copper in appearance.

"The second is a green mineral called *malachite.* The third is *cuprite*, a red ore of copper; and the last is a brassy-looking crystalline mineral

called *copper pyrites.* These are the principal minerals from which we obtain our supplies of copper.

"Then, here are two specimens of the pure metal, which illustrate two important properties. One is copper-leaf, and it shows that copper can be beaten out into very thin sheets. The other is a very long and thin copper wire, which serves to show how well it can be drawn out."

"Why is copper sometimes used for making kettles and boilers?" asked Harry. "Is it better than iron?"

"Yes, it is better than iron, for it does not rust so readily. It does not combine with oxygen when cold, but it does do so slowly when heated."

Mr. Wood then proved this by putting a piece of copper wire into a gas flame till it was red-hot, and after it had cooled it was covered with a very thin layer of a black oxide.

"I will now perform an experiment to show the solubility of copper," said he.

He put a small piece of copper into a test-tube, and added a little nitric acid. A reddish-brown gas then came off, and the copper was soon all dissolved.

44. GOLD.

When the boys arrived on the following Friday evening, they saw Mr. Wood lifting a very thin sheet of bright-yellow metal out of a little book in which he had been keeping it.

It was so very thin that it had to be lifted with care, or it would have been broken or torn.

Just as he was doing this, Bob entered the room, for he had not come with the other boys that evening; and a draught of air from the open door caught the piece of metal and carried it away as easily as if it were a very light feather.

It was torn in several little pieces, and Mr. Wood passed one of the pieces to each of them that they might examine it.

"I say, how light it is!" exclaimed Harold.

"Light, did you say, Harold? Why, this is one of the heaviest of metals. It is more than nineteen times as heavy as water."

"What! heavier than mercury?" exclaimed Bob.

"Yes, heavier than mercury, which is, you remember, only about thirteen times as heavy as water."

"That's another puzzle," said Harold. "What a number of puzzles there are in chemistry!"

"No puzzle at all, Harold. You are deceived by the extreme thinness of the metal. It is gold, and gold can be beaten out into such thin leaves that a

great many thousands of them would be required to make a pile only one inch high. In fact, it can be beaten thinner than any other metal. It can also be drawn out into very thin wires."

"Gold is really a very hard metal, is it not?" asked Bob.

"Not at all hard," replied Mr. Wood, taking a gold coin out of his pocket. "Harold would no doubt like to try this with his knife," he continued, but I cannot allow that this time, for sovereigns are too valuable to be cut up."

"What makes gold so valuable?" asked Tom.

"It is valuable partly because it is scarce, and partly because there is such a demand for it for ornamental purposes and for use as money.

"It is, as you know, of a very rich yellow colour, and it does not rust when exposed to air, not even when strongly heated.

"It is always found pure in nature, not combined with other elements like most of the metals. We obtain it principally from very hard rocks, but small grains of it are met with in the sands of some rivers."

Mr. Wood then showed the boys a piece of quartz from South Africa, in which they could see little particles of gold arranged in streaks.

"How can all these little grains be taken out of the quartz?" inquired Tom.

"The quartz is crushed to a powder, and then

most of the quartz can be washed away, leaving the heavy gold behind. Mercury is next mixed with the powder, and this dissolves out every particle of the gold."

"But then they have to get the gold out of the mercury," remarked Harry.

"Just so; but that is easily done, for the mercury can be readily boiled away, and then the pure gold is left behind."

"Is all the mercury wasted?" asked Tom.

"Oh, no! When it is boiled the mercury comes away as vapour, and is all condensed in a cold vessel, and thus the same mercury can be used over and over again.

"Now," continued Mr. Wood, "I want you to observe carefully while I perform an experiment.

"I put some gold-leaf into a glass, and pour on it some strong hydrochloric acid. But the acid has no effect on the metal.

"Next, I put some more gold in a second glass, and add strong nitric acid, and even this has no effect.

"Now I take a third vessel, and put into it some gold, with a mixture of both these strong acids, and then you see the metal gradually disappear, while the liquid turns yellow.

"This mixture of hydrochloric and nitric acids is called *aqua regia*, which means 'royal water', and it is so called because it will dissolve the royal

metal, gold. Jewellers use this mixture for testing gold.

"I told you just now that gold is not a hard metal. It is really nearly as soft as lead when pure, and therefore would not be very durable. Consequently, the metal used for coinage and jewellery is always mixed with copper, the mixture being very much harder than pure gold.

"English gold coins consist of a mixture of gold and copper in the proportion of eleven parts of the former to one of the latter, and this is known as 'standard gold'."

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45. IRON.

"What metal for this evening, Mr. Wood?" asked Harold, before he had even allowed himself time to sit down.

"Well, Harold, you certainly deserve to get on well with your chemistry, for you always seem very anxious that no time should be wasted. Our lesson is to be about the most useful of all the metals, and which do you think that is?"

"Gold," said Harold promptly, thinking at the time of all the fine things he could buy if only he had a gold coin.

"Oh, no! not gold, Harold. Gold is certainly one of the most valuable of the metals, but the

world could get along very comfortably without it. There is another metal, however, that we should very much miss."

"I think iron is the most useful of the metals," said Harry, "because so many useful things are made of it."

"That is *my* opinion too," said Mr. Wood; "and it is iron that I am going to talk to you about this evening.

"Here are three pieces of the metal, and I want you all to examine them carefully."

As soon as this was said, out came Harold's pocket-knife, and in a moment he was scratching away at the specimens, and trying to chip off small pieces.

He found that he could make a slight mark on one of them, but not on the others, and he asked why, if all three were iron, they were not equally hard.

Mr. Wood explained the mystery by telling them that there are three varieties of iron—*wrought iron*, *cast iron*, and *steel*.

"Wrought iron," he said, "is the softest kind of iron, but the other two are very hard, and steel especially so."

He then showed that a file, which was made of steel, would easily cut wrought iron, but that it would not cut cast iron so readily.

He also took three thin bars—one of wrought iron, one of cast iron, and one of steel—and told the boys to break them.

The wrought iron was soon bent, but it was so tough that they could not break it. Harold snapped the cast iron in two with his strong hands, but could not do so with the steel.

He was then told to try it with a hammer, and soon it snapped in two like the cast iron. The piece of wrought iron was then hammered, and it was quickly flattened out, but would not break.

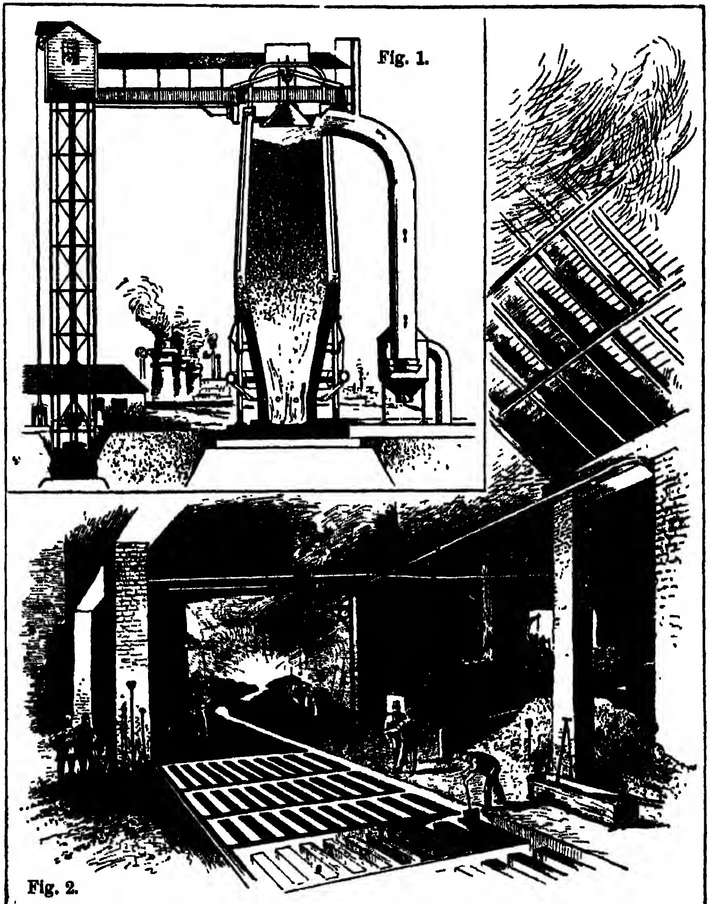
"Of course you all know what iron rust is," said Mr. Wood, "for we have said something about it before."

"You told us it is iron oxide," said Harry, "formed by the iron combining with oxygen in the air."

"Yes, that is so; and iron has such an attraction for oxygen and other elements that it is seldom found pure in nature.

"Here are some pieces of different iron ores. The first is an iron oxide called *hæmatite*, of a very dark reddish colour; the second is *iron pyrites*, a brassy-looking mineral containing iron and sulphur; and the other is *clay ironstone*, a mineral containing iron carbonate with clay.

"We obtain most of our iron from clay ironstone. The ore is put into a very hot furnace with coal and lime. The heat of the furnace drives off carbonic acid gas from the carbonate, and the carbon of the coal combines with the remainder of the oxygen, converting it into carbonic acid gas.



Iron Manufacture.

Fig. 1. Section of Blast-furnace in operation.
Fig. 2. Tapping the Furnace and running the molten metal into moulds (thus forming "pigs").

"The lime then combines with the clay, forming a glassy substance called *slag*. The melted iron runs to the bottom of the furnace, and the melted slag, which is lighter, floats on the top of it.

"A plug is then drawn at the bottom, and the melted iron runs out into grooves made in sand, where it soon becomes solid.

"The iron thus prepared is cast iron, and the pieces go by the name of *pigs*. It contains a certain amount of carbon. In fact, all the varieties of iron contain more or less carbon, as well as small quantities of other substances; and these render the iron harder than it would be if perfectly pure. Pure iron is never used for manufacturing purposes, being much too soft.

"Steel and wrought iron are prepared from the rough cast-iron pigs. The former contains less carbon than the cast iron, and wrought iron still less than steel, being the purest as well as the softest of the three kinds."

Mr. Wood now showed that the three chief mineral acids—sulphuric, hydrochloric, and nitric—all dissolve iron. He put a very small piece of iron in each of three test-tubes, and added to each a different acid.

In each case the liquid became black and dirty, owing to the carbon and other impurities that were separated from the metal.

46. TIN AND ZINC.

"Who can tell what metal this is?" said Mr. Wood, holding out a strip of whitish metal, at the commencement of his next lesson.

They all examined it in turn, and gave their opinion about it.

Tom thought it was tin; but Harry said it was of a darker and duller colour than his tin box. Harold said it was lighter in colour than iron, and was not so hard.

It was zinc, a metal which is used extensively for covering the roofs of houses and for lining water cisterns.

The next specimen shown to the boys seemed to puzzle them quite as much, for nobody could tell what it was.

"It is a piece of 'galvanized iron'," said Mr. Wood, "a name which is given to iron that has been covered with a layer of zinc in order to preserve it.

"Although zinc is softer than iron, still a coating of zinc preserves iron. You know that iron rusts rapidly when exposed to air, and that it would, in time, all turn to rust; but zinc is not changed much by the atmosphere, and therefore it is a good material for protecting iron from air.

"This pail is made of galvanized iron," continued Mr. Wood. "There is no need to paint it in order

to protect it from the atmosphere, but iron that is not covered with a coat of zinc or some similar metal must be painted to preserve it from rusting.

"Zinc can be rolled or beaten out into thin sheets, and it is chiefly in that form that it is used.

"Here is a very thin strip of zinc. Let us see what takes place when it is heated."

The strip of zinc was then held in the gas-flame, and it very soon began to melt, and presently to burn with a brilliant bluish-white light.

Three little pieces of zinc were then placed in three test-tubes, and a little acid was poured on each—hydrochloric acid on one, sulphuric acid on another, and nitric acid on the third. In all three cases the metal was dissolved.

"I have another metal to show you now. What do you think this is?" said Mr. Wood, holding up a piece of the metal to which he referred.

"Oh, that's a piece of sheet-tin!" said Harold; "the metal used to make tin boxes and tin kettles."

"Now, look here, Harold," said Mr. Wood; and as he said this, he held a magnet against the metal and lifted it up.

"You see how the magnet lifts the metal. That proves that it is not tin, for a magnet will not lift tin."

"It can't be iron," replied Harold, "for, look, I can scratch it easily with my knife; and it is of a bright white colour."

"Well, I shall have to tell you what it is, Harold. It *is* the metal used for making 'tin kettles' and 'tin boxes', but 'tin kettles' and 'tin boxes' are made of iron."

"Are you really in earnest?" said Harold, as the other boys were having a good laugh at the joke.

"To be sure I am," replied Mr. Wood, smiling. "Now let me finish what I have to say. The goods we call 'tin goods' are all made of iron, but the iron is covered over with a thin layer of tin to prevent it from rusting, for tin does not rust on exposure to air.

"When you scraped this piece of metal just now with your knife, it appeared very soft; but you were only scraping off the soft tin that covers the surface of the iron."

"Oh, I understand now!" said Harold; "but I should like to see a piece of pure tin."

"Here is a piece, then," said Mr. Wood, as he handed over a long and thin stick of white metal.

It was so soft that they could bend it quite easily, and it was easily cut in two by Harold's knife.

"Hold this piece in the gas-flame, Harold," said Mr. Wood.

And Harold forgetting for the time all about the piece of copper that burnt his fingers many weeks before, held a short piece of tin in the flame.

It began to melt almost immediately, even more

quickly than lead would have melted; but it was not long before Harold was obliged to throw down the piece of tin, for the heat soon travelled through it to his fingers.

Part IV.—ORGANIC CHEMISTRY.

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47. ANIMAL AND VEGETABLE SUBSTANCES—SUGAR.

"You know, boys, that all substances belong to one of three groups—animal, vegetable, or mineral.

"We have been learning chiefly about mineral substances, but now I shall give you a few lessons on some very useful things that we get from plants and animals. We will begin with sugar.

"I will put a little sugar in a glass tube, and heat it in the gas-flame. Now watch the changes that take place."

This the boys did. They saw the sugar melt, and then turn quite black. They also saw vapours coming off, and water settling on the cold part of the tube; and when all the changes were over, nothing was to be seen at the bottom of the tube but a black and dry mass which they were told was carbon.

"Now, what does this teach us about sugar?" asked Mr. Wood.

"It shows that sugar contains carbon," said Tom.

"And also that it contains hydrogen and oxygen," added Harry.

"Yes, sugar contains these three elements—

carbon, hydrogen, and oxygen; and they are the only elements it does contain.

"All animal and vegetable compounds contain carbon, and a large number of them contain hydrogen and oxygen also.

"We will now dissolve some sugar in a little water. Do you think this glass of water will dissolve a glass full of sugar? Let us try."

Then lump after lump of sugar was put into the water while the mixture was being stirred, and the whole glass of sugar finally dissolved.

More was then added, and still the water dissolved it; and, at last, three glassfuls of sugar had all been dissolved in the one glass of water, forming a thick syrup.

"Now we will see if more sugar will dissolve when we apply heat," said Mr. Wood, and the vessel containing the syrup was allowed to stand in a larger vessel of boiling water.

More sugar was added, and it continued to disappear in the liquid; and when it was hot, it seemed as if any amount of sugar could be made to dissolve in the small quantity of water, though, towards the end, it dissolved very slowly.

The vessel of syrup was now taken out of the hot water, and placed in cold water.

After a time a layer of crystals began to form on the top, and some were also seen on the bottom of the glass.

"Now you can see how sugar-candy is made," said Mr. Wood; "only, if large crystals are required, it is necessary to use very large vessels, and to give sufficient time for the crystals to form."

Crystals of Sugar (Sugar-candy). *a, b,* Separate crystals.

"Do tell us how to make barley-sugar," said Harold.

"Well, I will make a little," was the reply. And Mr. Wood at once set to work.

He put some sugar into a copper vessel, with a very little water at the bottom, only just enough to prevent the sugar from burning.

This was then heated gradually over the gas till all the sugar had melted, and the melted sugar was poured out on a slab of marble.

Here it cooled rather quickly, and was soon solid, though still soft and flexible.

"That looks like fine barley-sugar," said Harold, "but how do they get it in those curly sticks?"

"That is very easily done," said Mr. Wood; and

in a minute or two, the flat cake of barley-sugar had all been cut into strips, and twisted up just like the sweetmeat the boys knew so well.

48. MORE ABOUT SUGAR.

"This evening I shall have something more to tell you about sugar, and first of all we will learn how it is obtained.

"Most plants contain a certain amount of sugar, and some a very large quantity.

"Sometimes it is most abundant in the root, as in the beet-root and carrot; sometimes in the stem, as in the case of the sugar-cane; and the juices of most fruits contain a kind of sugar.

"Most of the sugar we use is obtained from the sugar-cane, but we also get large supplies from beet-root."

"How do they get the sugar out of the sugar-cane?" asked Bob.

"The juice of the cane is first pressed out between rollers, and then it is boiled with lime."

"Boiled with lime!" exclaimed Harold; "that must make it very unpleasant."

"Oh, no! it doesn't. In fact the lime makes it better than before, for it combines with some of the impurities, causing them to separate from the sugar, and float as a scum on the top."

"Then, I suppose, they skim this off, just as my mother skims off the scum when she is making jam?"

"Just so; and then the juice is boiled till it

Sugar-cane.

becomes a very thick syrup, such as we made last week, only it is brown."

"And I think I can tell what they do next," added Harry. "They let it cool, as we did, to get the crystals of sugar."

"Yes, that is right. The sugar thus obtained is brown; and that portion of the liquid which does not become solid is known as *molasses* or *treacle*."

"But how do they make white sugar?" asked Tom.

"The white sugar is obtained from the brown in this way:—It is again dissolved, and the solution is filtered through animal charcoal, that is, charcoal prepared by charring animal matter, and then it is boiled again to drive off the water and form the crystals."

The boys listened carefully to this short account of the preparation of sugar, and then Harry asked whether the sugar obtained from the beet-root was the same kind as that from the sugar-cane.

"It is just the same," replied Mr. Wood; "but as we obtain most of that kind from the sugar-cane, it is generally spoken off as *cane-sugar*.

"There are other kinds of sugar, however, obtained from various sources. That found in the juice of the grape and many other fruits is called *grape-sugar*; and another kind, obtained from milk, is called *milk-sugar*."

Mr. Wood then showed the boys some grape-sugar, and gave them all a little piece to taste. He told them not to bite it, so that they might notice what a long time it took to dissolve in the mouth.

Harold said he liked it better than ordinary sugar, because it didn't dissolve so quickly, and so he could enjoy it for a longer time.

Then Arthur performed an experiment.

He had to weigh out equal quantities of loaf-

sugar and grape-sugar, and then dissolve them both in separate glasses of water.

The loaf-sugar soon dissolved, but he had to stir the water in the other glass for a long time before all the grape-sugar had disappeared.

Then, much to Harold's satisfaction, they had to taste the solutions and say which was the sweeter of the two. And they all agreed that the loaf-sugar was the sweeter.

Mr. Wood now performed an experiment. He opened a jar of honey, and put a large spoonful of it into a glass.

He then poured some spirit on it, and gave it to one of the boys to stir with a glass rod.

After a short time the liquid was poured off, some fresh spirit added, and stirred again.

The liquid was again poured off, leaving a coarse powder at the bottom of the glass.

This powder was then transferred to an evaporating basin, and gently warmed till it was dry. It was then given to the boys to taste.

"That substance is grape-sugar," said Mr. Wood —"the same kind of sugar that we get from fruits. The spirit dissolved away the other parts of the honey, but would not dissolve the sugar, which was therefore left at the bottom."

Then, at the end of the lesson, Mr. Wood showed them some little crystals of milk-sugar that he had prepared from milk.

49. STARCH.

When the boys entered Mr. Wood's study the following week nobody was there, but the apparatus and materials were all ready for the lesson.

They were much amused at what they saw, and made many guesses as to the subject they were to hear about.

There was a potato, a knife, a piece of string, a piece of rag, a cup of flour, a piece of bread, some starch, a pestle and mortar, a basin, a few glasses, some bottles of chemicals, and a microscope.

They did not have to wait long, however, for their teacher soon entered the room, and told them that the lesson was to be on starch.

"I think I have an experiment for each of you this evening," he said.

"Now, Bob; your turn first. Put a little starch into this glass tube, and heat it in the gas flame."

In a minute Bob was at work; and as soon as he applied heat to the tube the starch began to turn black, vapours were given off, and water settled on the sides of the tube at the top.

"Now, Bob; what does your experiment teach us?"

"It shows us that starch contains carbon," replied Bob.

"Yes; and that it contains hydrogen and oxygen, too," added Harry.

"You are both right," said Mr. Wood. "The black substance left in the tube is carbon; and the water formed by heating the dry starch proves that it must have contained hydrogen and oxygen.

"Now for your experiment, Arthur. Rub up a little of the starch in a mortar with some water. Then put a little of the mixture into a test-tube, add more water, and tell me if the starch dissolves."

When Arthur had done this he was not quite sure whether the starch had dissolved or not. The liquid was white, but it did not seem to contain any solid particles. But it had not dissolved; for when it was allowed to stand for a time, all the starch settled to the bottom, leaving the clear water above it.

Arthur was then told to shake up the starch with the water and boil it; and when he did so the liquid became nearly transparent, for the starch had dissolved.

"Harry's experiment next," said Mr. Wood. "Take this solution of iodine and add a few drops of it to a mixture of starch and water."

When this was done the starch turned to a dark colour; and Harry was then told to pour a drop or two of the iodine solution on a piece of bread, and a drop or two on a slice of potato. Both bread and potato also turned blue, showing that they both contained starch.

"Now I have an experiment for Harold," said Mr. Wood, "and Tom shall help him."

Harold had to cut a potato in two, and rub the two flat surfaces together over a basin, while Tom let water drop on the potato from above.

A whitish substance was thus washed out of the potato, and fell into the basin. This substance was then allowed to settle at the bottom, and most of the water was drained off.

Harold then had to pour a few drops of iodine solution on it, and it turned blue, thus proving that it was starch.

Now came Tom's turn. He put a little flour on a piece of calico, tied it up in the calico with a piece of string, and squeezed it well for some time in a basin of water.

The water soon became milky in appearance, but he had to continue pressing away at the flour till there was nothing left except a very sticky substance.

After a time the white powder which had been squeezed out through the calico settled at the bottom of the basin. They poured off the water, and found that the powder was starch, for the iodine turned it blue.

"Now I will show you my experiment," said Mr. Wood; and he cut off an exceedingly thin slice of potato, no larger than a threepenny-piece, and so thin that you could see through it.

He put this on a slip of glass, and placed the glass under the microscope.

Grains of Starch under the Microscope.

They were then told to look through the instrument, and they all saw a large number of grains of starch that were really very small indeed, but were made to appear large when seen through the powerful glasses.

50. A TALLOW CANDLE.

"Our lesson this evening is to be on a tallow candle," began Mr. Wood, as the boys seated themselves around his study table.

Then he showed them two candles, one made of a rather hard waxy-looking substance; but the other formed of a soft fatty material.

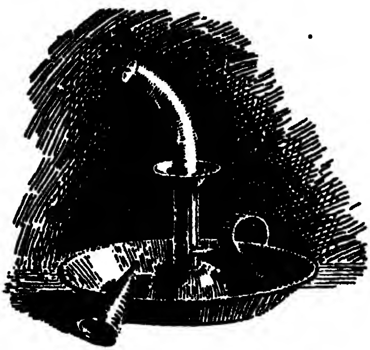
"I have never seen a candle like that before," said Harry, pointing to the latter; "how soft and greasy it is."

"*I* have seen them," said Harold, "but never alight. My father always keeps a candle like that in his workshop to grease his saws so that they shall not rust."

"This candle," said Mr. Wood, "is made of tallow, which is the name given to the fat obtained from the ox, sheep, and other animals. It is not

much used now for candles, but when I was a little boy, tallow candles were very generally employed in lighting our houses.

"The other candle is made of stearic acid, a substance which is prepared from tallow, but which is not a fat. It is the kind of candle most commonly used nowadays in places where they do not use gas or oil-lamps."



A Tallow Candle in hot weather.

A little piece of each of the candles was then cut off and put into a vessel of cold water, which was afterwards gradually heated.

The substances would not dissolve in water, not even when the water was heated, but both melted and floated on the top of the hot water.

The tallow melted much more quickly than the stearic acid, a fact which Mr. Wood pointed out as explaining why tallow is not so good as stearic acid for making candles. In hot summer weather tallow becomes so soft that a candle made of it will bend with its own weight.

Mr. Wood now lighted the tallow candle, and held a dry glass jar over the flame for a few seconds. Water settled on the surface of the glass inside, making it quite wet.

"We had that experiment before," said Harry, "but with another kind of candle. It proves that the candle is made of a substance containing hydrogen."

"Very good, Harry. And now I will repeat the experiment, and shake up the gas formed by the burning candle with lime-water.

"You see that the lime-water turns milky. What does that show?"

"I remember," cried Harold. "It shows that there is carbon in the tallow, for there must have been carbonic acid gas in the jar to turn the lime-water milky, and it is the burning of carbon that produces carbonic acid gas.

"We have seen," said Mr. Wood, "that tallow contains hydrogen and carbon. It also contains oxygen; and all kinds of fats and oils are composed of the same three elements.

"Now, I have another question for you. If you have some sugar on your hand, you can easily wash it off with water; but if you have tallow or any kind of fat or oil on your skin, water will not wash it off. What is the reason?"

Harry was the first to answer. "It is because water will dissolve sugar, but will not dissolve fat," he said.

"That is right, Harry. Then if we want to clean anything that is greasy, we must use a liquid that will dissolve fats and oils.

"Several liquids will do this, among them being ether, naphtha, and benzine; and these are very useful for removing grease stains from paper, cloth, or any other substance."

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51. SOAP.

"I suppose you would like to learn something more about tallow this evening," said Mr. Wood, introducing his next lesson.

"Yes, we should," was the reply.

"Very well, then; I will show you how to get a very useful substance from it."

Mr. Wood then put some water into a large glass flask, dropped into it a lump of tallow, and put it on a stand over a gas-burner.

As the water became heated, the tallow melted, and floated on the surface in the form of a transparent and almost colourless liquid. The water soon began to boil, and then Mr. Wood poured into the flask a solution of an alkali called *caustic soda.* He was careful to explain that this was not the same substance as *washing soda.*

The fat began to change at once in appearance. The liquid in the flask began to froth up, and soon the water was no longer clear and transparent.

More caustic soda was added, a little at a time, and the boiling continued till at last all the fat had

entirely changed, and the liquid looked very soapy.

"A chemical change, which I will explain to you, has taken place in the flask," said Mr. Wood.

"You know that tallow contains stearic acid. When it is boiled with caustic soda, the alkali combines with the stearic acid, forming soap, which is dissolved in the boiling water.


Making Soap.

"I will now throw some common salt into the flask. It dissolves almost immediately, and then the liquid gradually becomes clear and transparent once more."

"But what is that substance which forms a layer on the top of the water?" asked Tom.

"That is the soap. It floats on the top because it will not dissolve in salt water."

The whole contents of the flask was then poured out into an earthenware vessel, which was placed in a larger vessel of cold water in order that it might cool rapidly.

Before the boys left, the soap had become a solid cake, covering the top of the clear liquid.

As they were going away, Harold said he should make some soap, and asked Mr. Wood whether he might boil the materials in a saucepan instead of a flask.

"Yes," said Mr. Wood. "I used a flask so that you might better observe the changes that took place, but an old saucepan will answer the purpose well."

52. SPIRIT.

"Here is a bottle of a liquid which looks just like water, but it differs from water in many respects. It is *alcohol* or *spirit*, and we are going to learn something about it this evening."

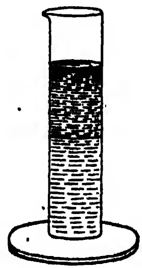
After this introduction from Mr. Wood, Bob carefully examined the bottle, and said he couldn't see that the liquid differed from water at all; but he was told to remove the cork and smell it. He was also allowed to put his tongue to the wet cork in order to taste it.

There was then no doubt about the difference, for the liquid had a strong odour, and a burning taste. Other important differences were illustrated by several simple experiments.

There were two little basins on the table, each containing a small piece of sponge; and a little water was poured into one, and spirit into the other. The two pieces of wet sponge were then rubbed

on a blackboard so as to produce two wet streaks, and the boys were told to watch and see which would dry first.

In less than a minute the spirit had evaporated entirely, but the streak of water remained visible for some time after the other had disappeared.



Coloured Spirit floating on Water.

"You see that the spirit dries rapidly," said Mr. Wood, "because it quickly changes from a liquid to a gas when exposed to air. Liquids which, like this, turn rapidly to vapour, are said to be volatile."

Mr. Wood then took a tall, narrow, glass vessel, half-filled it with water, and then filled it up with spirit which he had coloured with a little dye.

He poured the spirit in very gently, and it floated on the top of the water, proving that it was lighter.

The two liquids mixed a little just where they met, for you could see the colour of the spirit descending just a little way into the water, but otherwise they remained quite unmixed.

Now, Mr. Wood closed the top of the glass with his thumb, inverted it two or three times, and then asked the boys to say what they noticed.

"They have mixed now," said Harold, "and the spirit does not come to the top again as oil would."

"Yes, Harold; and that shows that spirit dissolves in water."

The next experiment was this:—A test-tube containing spirit was floated in a vessel of water, and the water was heated over the gas-burner. The water soon became hot, and, of course, the heat also passed into the spirit; but it was noticed that the spirit boiled first, thereby showing that it boiled at a lower temperature than water.

Mr. Wood then told the boys that many substances which would not dissolve in water dissolved readily in spirit, and that other substances which dissolved in water would *not* dissolve in spirit.

To prove this he put some sugar in spirit, and it did not seem to dissolve at all; but a kind of gum he had which was quite insoluble in water he soon dissolved in spirit.

He stated that many of the varnishes and polishes used for our furniture were made by dissolving gums in spirit, and he used the solution of gum that he had made to varnish a piece of wood.

It quickly dried, because the spirit was very volatile, and a thin layer of the gum was left behind on the wood, giving it a very glossy appearance.

In conclusion, he showed the boys some small animals that had been in bottles of spirit for several years, and this he did to let them see how useful spirit is for preserving things, that is, for preventing them from decaying.

53. MORE ABOUT SPIRIT.

"Spirit is such a valuable and interesting liquid, that I am going to tell you more about it this evening. First of all, we will see if it is combustible. There, when I put a match to it, you observe that it burns with a very pale blue flame, giving hardly any light.

"I now hold a glass rod in the flame, and it does not become black as it would if put in a gas or candle-flame, because, when spirit burns, all its carbon is converted at once into carbonic acid gas."

"Is alcohol obtained from plants?" asked Harry.

"Yes; it is produced in many vegetable substances by natural changes which take place in them. Thus, when the juice of grapes is exposed to air, the grape-sugar in it is slowly turned into spirit, converting the liquid into wine. But let us prove that the spirit really contains carbon."

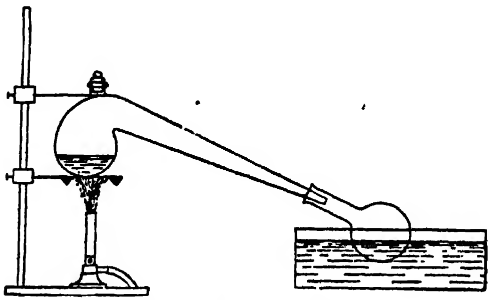
A little spirit was then poured out into a basin, and set on fire. A glass vessel was held over the flame. It immediately became wet, and when the gas produced by the combustion was shaken up with lime-water, the lime-water turned milky.

"That's just what you did with the candle-flame," remarked Tom.

"It is, Tom; and the result proves that spirit, like tallow, contains carbon and hydrogen. Like tallow, too, it contains oxygen as well.

"Now we will have another experiment," said Mr. Wood; and he poured a little ale into a glass retort, put a gas-burner beneath to boil the ale, and placed a flask to catch the vapours given off.

The flask was resting in a vessel of cold water, so



Apparatus for obtaining Spirit from Ale.

that it might be kept cool during the whole of the experiment, even though hot vapours went into it.

In a few minutes the ale began to boil, and the vapours given off were condensed or changed back to the liquid state as they passed into the cold flask.

The ale was allowed to boil slowly for a minute or two, and at the end of that time there was about a teaspoonful of colourless liquid in the flask.

This was poured out into a small basin, and passed round for the boys to smell. It no longer smelt like ale, but like strong spirit.

Mr. Wood then put a light to it, and it burned

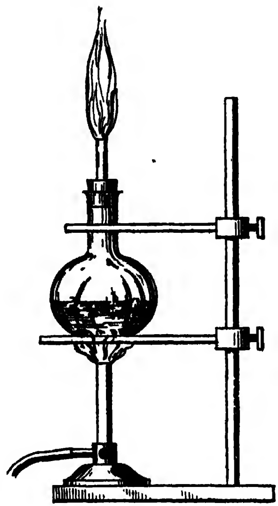
with a pale-blue flame, just as they had seen the spirit burn a little time before.

"Is spirit made in this way?" asked Bob.

"I can hardly say that I *made* the spirit, Bob, for it existed in the ale before Ale contains a large quantity of water and a small amount of spirit, and I have shown you how we may get the spirit from it.

"Of course you know that, when water boils, steam is given off, and condenses or changes back to the liquid state when it is cooled.

"Alcohol behaves in a similar manner when heated. Alcohol vapour is given off, and changes back to liquid alcohol when cooled.



Combustion of Alcohol obtained from Ale.

"Now, both these changes took place in the flask. Both water vapour and alcohol vapour passed into the flask, and both condensed, forming a mixture of liquid water and alcohol.

"But, you remember that alcohol is a very volatile liquid, that is, it is changed into vapour much more easily than water. Therefore, when heat is applied to ale, though both water and alcohol pass off, the greater portion of the alcohol comes off at

the commencement, and that is why I did not boil away more than about a teaspoonful of the ale.

"*Spirits of wine*, which we can buy at the chemist's, is alcohol from which only a part of the water has been removed; and *methylated spirit* is spirits of wine mixed with another liquid called *wood spirit.*"

Mr. Wood showed the boys one other experiment. He put some ale into a flask which was fitted with a cork and tube. He heated this; and then, just when it commenced to boil, he put a lighted match to the tube, and the alcohol vapour that was given off caught fire, and burnt with a large blue flame.

But it did not burn long, for the greater part of the alcohol was soon gone, and then but little came off except water vapour.

54. VINEGAR.

"You remember I told you that the juice of the grape, if exposed to air, underwent a chemical change, becoming wine.

"Now, if the wine thus produced be shut off from the air in bottles or in casks, the chemical action ceases; but if it be left exposed to air for a longer time, another chemical change takes place, for the alcohol is slowly changed into an acid, and the liquid is then called *vinegar*.

"Harry, I want to see if you can prove to us that there is an acid present in this vinegar."

Harry remembered how to do this. He poured some water into a glass, coloured it with a few drops of litmus solution, and then added a little vinegar. It turned to a bright-red colour at once.

"What is the name of that acid?" asked Tom.

"It is called *acetic acid*, Tom. Here is a bottle of pure acetic acid. You see it is quite colourless like water. If you smell it you will at once find that it resembles ordinary vinegar, but it is much stronger, for vinegar contains a large quantity of water."

"Oh, now I know what turns cabbage red when it is pickled!" said Harold.

"Yes, the cabbage generally used for pickling is of a purplish colour, and the acetic acid of the vinegar turns it red just as it turns litmus.

"Here is another example of the power of the acid," continued Mr. Wood, as he put a blue flower into a glass containing a little acetic acid; and it was not long before the flower began to change to a bright-red colour.

"My mother sometimes uses *white* vinegar for pickling," said Bob. "What is white vinegar?"

"Just watch this experiment, Bob, and you will soon see."

Mr. Wood then put some ordinary brown vinegar into a retort, and boiled it, and allowed the vapour

to pass into a cold flask just as he had done when he boiled some ale.

When it had boiled for a few minutes, Mr. Wood was able to point out some white vinegar in the flask, for, as the vapour passed off, it left all the colouring substance behind in the retort.

He then told the boys that white vinegar was not always made in that way, for some persons bought the pure acetic acid, and added water to it to reduce its strength, thus producing good white vinegar.

Tom was then sent into the kitchen to get some pickled cabbage. A little of it was put in a saucer, and some powdered soda sprinkled on it.

"Oh, look!" exclaimed Harold, "it is all turning blue."

"Yes; and why does it turn blue, Harold?"

Harold was puzzled, but Harry helped him out of his difficulty, for he remembered that soda was an alkali, and that alkalies destroyed acids, and turned vegetable reds blue.

SUMMARY.

Part I.

Lesson 1.—WHAT IS CHEMISTRY?

Chemistry teaches us—

(*a*) What substances are made up of.

(*b*) How to break up certain substances into the simpler ones of which they are composed.

(*c*) How to cause substances to combine and form new substances.

(*d*) To understand many of the wonderful changes that are continually taking place around us.

Lesson 2.—ELEMENTS AND COMPOUNDS.

1. An element is a substance which cannot be broken up into simpler substances. Quicksilver is an element.
2. A compound is a substance that is made up of two or more elements. Water is a compound.
3. When mercury oxide is heated, it is split up into mercury (quicksilver) and oxygen. Therefore it is a compound.
4. The mercury forms a shining deposit on the side of the tube in which the oxide is heated.
5. The oxygen is driven off as a gas, and will cause a smouldering taper to burst into a flame.
6. Oxygen and mercury are elements.
7. A compound is very different from the elements which compose it.
8. About seventy elements are now known.

Lesson 3.—BUILDING UP COMPOUNDS.

1. When heated mercury is exposed to air for a long time, it combines with oxygen, forming the red mercury oxide.
2. When the metal magnesium is heated, it combines with oxygen, forming magnesium oxide.

3. Both mercury and magnesium are elements, but the oxides formed when they are heated are compounds.
4. When iron (which is an element) is exposed to moist air, it combines with oxygen, forming a reddish compound which we call rust. But if the iron is kept dry this change does not take place.
5. A coating of paint or grease will prevent iron from rusting.
6. When iron is strongly heated it forms a black oxide.

Lesson 4.—METALS AND NON-METALS.

1. Elements are classified into metals and non-metals.
2. Four of the well-known elements are gases at ordinary temperatures. They are hydrogen, chlorine, oxygen, and nitrogen.
3. Hydrogen burns with a pale-blue flame.
4. Chlorine is of a greenish-yellow colour. It will not burn.
5. Nitrogen will not burn, and a taper will not burn in it.
6. Oxygen will not burn, but it supports combustion.
7. Two of the elements are liquid at ordinary temperatures. They are mercury and bromine. All the others are solid. The state in which an element exists depends on the amount of heat it contains.

Lesson 5.—METALS AND NON-METALS (*Continued*).

1. All the metals have bright surfaces.
2. They are good conductors of heat.
3. They will all melt, though a high temperature is necessary to melt some of them.
4. Metals cannot be dissolved without being changed into new substances.
5. The following is a list of the commoner elements:—

Non-metals.		*Metals.*	
Arsenic.	Iodine.	Aluminium.	Magnesium.
Bromine.	Nitrogen.	Antimony.	Manganese.
Carbon.	Oxygen.	Barium.	Mercury.
Chlorine.	Phosphorus.	Bismuth.	Platinum.
Fluorine.	Silicon.	Calcium.	Potassium.
Hydrogen.	Sulphur.	Chromium.	Silver.
		Copper.	Sodium.
		Gold.	Tin.
		Iron.	Zinc.
		Lead.	

Lesson 6.—MIXTURES AND COMPOUNDS.

1. When iron filings and flowers of sulphur are mixed they do not combine.
2. Both remain unchanged, and the iron may be separated from the sulphur by means of a magnet.
3. If the mixture be heated, the two elements combine and form a compound called iron sulphide, which is very different from either of its ingredients.
4. When elements combine chemically, they always do so in certain fixed proportions.

Lesson 7.—MATTER CANNOT BE DESTROYED.

1. When a candle burns, its elements are not destroyed, but simply changed in form.
2. The hydrogen of the candle combines with oxygen, and forms water.
3. Its carbon combines with oxygen, forming carbonic acid gas.
4. Both the water and the carbonic acid gas may be absorbed by means of caustic soda and then weighed.
5. They weigh more than the candle from which they were produced, the increase being due to the oxygen gained from the air.

Lesson 8.—SOLUTION AND SUSPENSION.

1. When alum or any other soluble substance is put into water, it disappears; but it is still in the water, having been changed into a liquid.
2. The mixture thus produced is called a solution.
3. The dissolved substance weighs just as much as it did when solid.
4. Some substances will not dissolve in water, but may be dissolved in other liquids.
5. Sulphur will dissolve in a liquid called carbon disulphide.
6. Chalk will not dissolve in water; but its particles remain solid, and float about in the liquid. The chalk is then said to be *suspended.*
7. The chalk may be separated from the water by allowing it to stand, and then pouring off the clear liquid. This is called *decanting.*
8. It may also be separated by filtering.

9. Dissolved substances will pass through a filter, but may be separated by boiling away the liquid.

Lesson 9.—MAKING CRYSTALS.

1. Water will dissolve a certain amount of alum, and no more.
2. When it has dissolved all it can it is said to be saturated.
3. Hot water will dissolve much more than cold water.
4. Cold water will dissolve as much common salt as hot water.
5. If a hot saturated solution of alum be allowed to cool, crystals are deposited.

Lesson 10.—CRYSTALS AGAIN.

1. When melted sulphur is allowed to cool, it forms delicate needle-like crystals, which grow larger and larger till they all join together into one solid mass.

   There are two methods of crystallizing a substance:—

   (*a*) By making a hot saturated solution and allowing it to cool.

   (*b*) By *melting* the substance and allowing it to cool.

Part II.—COMMON INORGANIC SUBSTANCES.

Lesson 11.—HOW TO ANALYSE THE AIR.

1. When phosphorus is burnt in a closed bell-jar standing in water, it combines with the oxygen of the air, and nitrogen remains.
2. As the oxygen is consumed, the water rises in the jar to take its place.
3. The water rises about one-fifth way up the jar, thus proving that oxygen forms one-fifth of the air.
4. When phosphorus combines with oxygen it forms an oxide of phosphorus, and this compound forms an acid when dissolved in water.

Lesson 12.—ABOUT NITROGEN.

1. Nitrogen will not support either combustion or life.
2. Nitrogen is so called because it is one of the elements of nitre (potassium nitrate or saltpetre).
3. The use of nitrogen in the atmosphere is to dilute or weaken the oxygen.

Lesson 13.—HOW TO MAKE OXYGEN.

1. Oxygen may be prepared by heating mercury oxide, but a high temperature is required.
2. It may be prepared more conveniently by heating a mixture of potassium chlorate and manganese oxide.
3. A glowing match placed in a stream of oxygen immediately burst into a flame and burns brilliantly.
4. Oxygen gas is not combustible.

Lesson 14.—EXPERIMENTS WITH OXYGEN.

1. A candle burns brilliantly in oxygen, forming both water vapour and carbonic acid gas.
2. The presence of carbonic acid gas in the jar in which the candle was burned may be proved by shaking up the contents with lime-water. The lime-water is turned milky.
3. Sulphur burns with a bright-blue flame in oxygen, forming sulphurous acid gas (sulphur dioxide).
4. When charcoal is burned in oxygen it forms carbonic acid gas.
5. Phosphorus burns very brilliantly in oxygen, forming an oxide of phosphorus.
6. Iron will burn in oxygen, forming black iron oxide.
7. These experiments prove that oxygen is a very powerful supporter of combustion.

Lesson 15.— THE AIR IS A MIXTURE, AND NOT A COMPOUND.

1. A simple mixture produced by adding one part of oxygen to four parts of nitrogen has exactly the same properties as the air we breathe.
2. The composition of a chemical compound never varies; but the composition of the air does vary slightly, and, therefore, we know it must be only a mixture of oxygen and nitrogen.

Lesson 16.—OTHER GASES IN THE ATMOSPHERE.

1. The air always contains water vapour and carbonic acid gas.
2. The presence of water vapour may be proved by exposing calcium chloride to the air. The calcium chloride becomes wet and increases in weight.

3. The water vapour arises from the surface of water (seas, rivers, lakes, &c.), and from the moist ground, and is given off by plants and animals.
4. When lime-water is exposed to the air, a thin film of calcium carbonate is formed on its surface. This proves the presence of carbonic acid gas in the air.
5. Carbonic acid gas arises from the ground in volcanic districts, and it is also given off by animals in breathing.

Lesson 17.—HOW ANIMALS AFFECT THE COMPOSITION OF THE AIR.

1. If we blow through a tube into lime-water, the lime-water turns milky. This proves that the air we breathe out contains carbonic acid gas.
2. The air we take into the lungs contains only *a little* carbonic acid gas; but that which we breathe out contains much more. A portion of the oxygen is absorbed into the body at every breath, and this is used up chiefly in forming the carbonic acid gas that is given out.

Lesson 18.—HOW PLANTS AFFECT THE COMPOSITION OF THE AIR.

1. If a plant is placed in a bell-jar quite full of water, and then exposed to sunlight, bubbles of gas arise from the plant and collect at the top of the jar.
2. This gas will cause a spark to burst into a flame. It is oxygen.
3. If a plant is placed in a jar of carbonic acid gas and exposed to sunlight, the carbonic acid gas is gradually taken in by the plant, and oxygen given off.
4. Carbonic acid gas is a plant food, and its carbon helps to form the solid parts of plants.

Lesson 19.—THE COMPOSITION OF PURE WATER.

1. Water may be decomposed into its two gases—hydrogen and oxygen—by means of the electric current.
2. When thus decomposed, the volume of the hydrogen formed is always exactly double that of the oxygen.
3. If hydrogen and oxygen be mixed in the proportion of 2 to 1, and a light applied, the two gases will combine with an explosion, forming water vapour.

Lesson 20.—HYDROGEN.

1. Hydrogen gas may be prepared by adding dilute sulphuric acid to pieces of zinc.
2. Pure hydrogen burns with a pale-blue flame, producing water vapour.
3. If mixed with air it is explosive.
4. Hydrogen is the lightest of all gases, and is sometimes used for filling balloons on that account.
5. Soap-bubbles filled with hydrogen rise rapidly; and the gas may be poured upward from one jar into another.
6. Hydrogen will not support the combustion of a lighted taper.

Lesson 21.—RAIN-WATER, SPRING-WATER, AND SEA-WATER.

1. Rain-water contains dissolved gas, which is obtained chiefly from the atmosphere.
2. When rain-water is heated this gas is driven off. It consists principally of carbonic acid gas.
3. If rain-water is boiled away, no deposit is left. It contains no mineral matter.
4. The water of springs, rivers, and lakes contains dissolved mineral substances, obtained from the rocks over or through which it flows.
5. Sea-water contains a very large quantity of dissolved mineral matter.
6. Pure water may be obtained from the water of springs, rivers, lakes, and seas by boiling and then condensing the steam given off. The mineral impurities are not driven off with the steam, but are left behind in the boiler.

Lesson 22.—CHALK, LIME, AND MORTAR.

1. Chalk is composed almost entirely of little shells.
2. When made very hot, carbonic acid gas is driven off, and lime only remains.
3. Lime is prepared for builders by burning chalk or limestone in a kiln.
4. When water is poured on lime, the two substances combine, producing much heat, and forming slaked lime.
5. Mortar is made by mixing slaked lime with water and sand.

Lesson 23.—CARBONIC ACID GAS.

1. Carbonic acid gas may be prepared by pouring dilute hydrochloric acid on chalk.
2. It is heavier than air, and will readily fall into any vessel.
3. It does not support combustion, neither will it burn.
4. A soap-bubble filled with air will float on the top of carbonic acid gas.
5. When passed into lime-water, the lime-water is turned milky.
6. Carbonic acid gas forms a weak acid with water.

Lesson 24.—CHARCOAL.

1. When wood is heated in a tube or in any closed vessel it does not burn, but a number of gases and vapours are driven off, and the wood is converted into charcoal.
2. If exposed to air when heated, it burns; and, when completely burned, nothing remains but a whitish ash, which consists entirely of mineral matter.
3. Charcoal is made in large quantities by covering heaps of wood with a layer of turf, and then causing it to smoulder slowly.
4. Charcoal is a variety of carbon, and carbon is an element.
5. Plumbago or black-lead is also a variety of carbon, and so is the diamond.

Lesson 25.—MORE ABOUT CHARCOAL.

1. When charcoal is heated in air, it forms carbonic acid gas; but this change will not take place while the charcoal is cold.
2. Lampblack is another variety of carbon. It is a kind of soot, and may be prepared by burning turpentine, when it is given off in the form of a very dense smoke.
3. All the varieties of carbon produce carbonic acid gas when burned in air or oxygen.

Lesson 26.—COAL.

1. Coal is formed from vegetable matter. The vegetable cells can often be seen in it by the aid of the microscope.
2. When coal is heated, coal-gas and various other substances are driven off, and coke is left.

3. Coal-gas contains carbon. A substance placed in a gas flame becomes blackened by a deposit of carbon.
4. When coal or coke is completely burned, an ash remains, and this ash consists of mineral matter.

Lesson 27.—COAL-GAS.

1. Coal-gas is lighter than air, and may be collected in an inverted jar, like hydrogen.
2. When coal-gas burns, water vapour is formed. Therefore it contains hydrogen.
3. Carbonic acid gas is also formed when coal-gas burns. Hence coal-gas must contain carbon.
4. Soap-bubbles blown with coal-gas rise rapidly in the air.
5. When coal-gas is mixed with air it is explosive.

Lesson 28.—FLAME.

1. A candle-flame consists of three distinct parts.—
   (*a*) A dark part in the middle.
   (*b*) A bright white part outside this.
   (*c*) A pale-blue part outside the white.
2. The dark inner part contains unburned gas, some of which may be drawn out through a small tube and then lighted.
3. The bright white part contains unburned carbon, and some of this carbon is deposited on anything that is held in the flame.
4. If air be blown into the flame, the carbon of the white part is all burned completely, and then the flame burns with only a feeble blue light, but gives more heat.

Lesson 29.—COMMON SALT.

1. Common salt is chloride of sodium. It contains sodium and chlorine.
2. It is a good preservative of animal and vegetable substances.
3. It is soluble in water, and the solution is called brine.
4. It dissolves as easily in cold water as it does in hot water.
5. If a solution of common salt be allowed to evaporate, little *cubical* crystals are formed.
6. Common salt is contained in sea-water. It is also obtained from brine-springs and from rock-salt.

Lesson 30.—CHLORINE.

1. Chlorine may be prepared from common salt by heating it with manganese oxide and sulphuric acid.
2. Chlorine is of a greenish-yellow colour, and is much heavier than air.
3. A candle burns feebly in chlorine, its hydrogen combining with the chlorine and forming hydrochloric acid, and its carbon going off in the form of smoke.
4. Turpentine burns in chlorine without being lighted, and the chemical action resulting is exactly the same as when a candle burns in the gas.
5. Phosphorus burns in chlorine without being lighted, and gives rise to a compound called phosphorus chloride.
6. Sodium combines with chlorine, forming common salt.
7. Copper leaf takes fire when plunged into a jar of chlorine, and copper chloride is formed.
8. Chlorine dissolves in cold water, forming a greenish-yellow solution.

Lesson 31.—BLEACHING.

1. Chlorine solution destroys the colour of litmus, logwood, indigo, and other vegetable dyes.
2. It will also bleach coloured flowers, but does not destroy mineral colours.
3. The gas will bleach as well as its solution, providing the substances to be bleached are moistened.
4. Chlorine will bleach writing ink and red ink, but not the marks made by black-lead and ordinary blue and red pencils.
5. When bleaching is done on a large scale, the coloured materials are rinsed alternately in a very dilute acid and in a solution of bleaching-powder.
6. Bleaching-powder is chloride of lime.

Lesson 32.—ACIDS.

1. Most acids turn vegetable blue colours red.
2. Some acids are solid (as tartaric and citric acids), some are liquids (as sulphuric, nitric, and acetic), and some are gases (as hydrochloric).

3. All acids contain hydrogen, and this hydrogen may readily be displaced by metals, thus forming salts.
4. Most acids have a sharp sour taste.

Lesson 33.—OIL OF VITRIOL.

1. Oil of vitriol (sulphuric acid) is not really an oil, but a liquid acid of a dense oily nature.
2. It is one of the most powerful acid substances.
3. When mixed with water great heat is produced.
4. When poured on sugar it combines with the elements of water (hydrogen and oxygen), leaving a black mass of carbon.
5. Nearly all animal and vegetable substances are charred in this way by sulphuric acid.

Lesson 34.—ALKALIES.

1. An alkali will restore the blue colour of litmus that has been reddened by an acid.
2. Alkalies destroy the properties of acids.
3. Caustic soda, caustic potash, and ammonia are the three most powerful alkalies.

Lesson 35.—WASHING SODA.

1. Washing soda is very soluble in water.
2. It is alkaline in character, for it turns reddened litmus blue.
3. When heated it melts, and gives off large quantities of water, and a white non-crystalline substance remains.
4. The crystalline structure may be restored by adding as much water as was driven off.
5. Washing soda is a carbonate. Carbonic acid gas is given off from it when an acid is added.

Lesson 36.—SALTPETRE.

1. Saltpetre (nitre or potassium nitrate) dissolves in cold water, but hot water dissolves much more of it.
2. When a hot saturated solution of saltpetre is allowed to cool, crystals are formed.
3. Saltpetre contains oxygen, and some of this oxygen is given off when it is strongly heated.

4. When saltpetre is mixed with charcoal, and the mixture lighted, the charcoal burns rapidly, the combustion being supported by the oxygen of the salt.
5. Gunpowder is made of saltpetre, charcoal, and sulphur.

Lesson 37.—SULPHUR.

1. Sulphur is a yellow solid, and a non-metallic elementary substance.
2. It is found largely in volcanic regions.
3. It also exists in combination with other elements in many abundant minerals.
4. Roll sulphur is prepared by melting sulphur and pouring it into moulds.
5. Flowers of sulphur is made by boiling sulphur and condensing the vapour given off.
6. Needle-like crystals of sulphur may be made by melting the substance and allowing it to cool.
7. Sulphur will not dissolve in water, but it is soluble in a liquid called carbon disulphide.
8. When the solution of sulphur is allowed to evaporate, eight-sided crystals are formed.

Lesson 38.—MORE ABOUT SULPHUR.

1. When sulphur is gradually heated it melts, forming a pale-yellow liquid, and afterwards turns darker and darker.
2. After a time it becomes thick like syrup, and if poured into cold water at this stage it forms plastic sulphur.
3. If heated to a higher temperature it becomes thin again, and then boils, giving off a very dark red vapour.
4. When this vapour cools, it forms a very fine crystalline dust called *flowers of sulphur.*
5. If heated still further, while in contact with air, the sulphur burns, forming sulphur dioxide (sulphurous acid gas).

Lesson 39.—CLAY.

1. Clay is formed when certain rocks are worn down by the action of water.
2. China clay (kaolin) is one of the purest kinds of clay. It is

formed by the action of water and air on granite and other rocks containing felspar.

3. Clay, when wet, can be moulded into any form.
4. It allows water to pass through it, but only very slowly.
5. When clay is baked it forms a porous kind of earthenware; but when earthenware vessels are intended to hold water, they are glazed.
6. Clay is composed of two compounds—silica and alumina.
7. Alumina is the oxide of a metal called aluminium.
8. Aluminium has a silvery appearance, and is very light. It does not tarnish when exposed to air, and is easily beaten into thin sheets and drawn out into wire.
9. When aluminium is mixed with copper it forms what is called "aluminium gold". This is very much like real gold, and keeps its colour well.

Part III.—COMMON METALS.

Lesson 40.—MERCURY.

1. Mercury is the only liquid metal. It is obtained chiefly from a mineral called cinnabar, which is composed of mercury and sulphur.
2. It is much heavier than iron, and, therefore, iron will float on it.
3. It boils at a much higher temperature than water does; and when it boils it gives off a vapour which readily condenses into little liquid globules.
4. Mercury does not tarnish on exposure to air unless heated, and then it combines with oxygen.
5. It will not dissolve in water, but dissolves readily in nitric acid.
6. Mercury dissolves many other metals, forming mixtures that are called amalgams.

Lesson 41.—LEAD.

1. Lead is a bluish metal, very soft and very heavy.
2. It does not rust, and is easily bent.
3. It is obtained chiefly from a mineral called galena, which is composed of lead and sulphur.
4. White lead and sugar of lead are compounds containing lead.

5. Litharge and red lead are both oxides of lead.
6. Black-lead contains no lead. It is a variety of carbon.
7. Lead easily melts.
8. Chrome yellow is a compound containing lead.

Lesson 42.—SILVER.

1. Silver is not very hard, and does not readily tarnish except where gas is burning.
2. Silver is not manufactured in a pure state, as it is rather soft. It is hardened by being mixed with a little copper.
3. It is the best of all conductors of heat.
4. It is sometimes found pure, but generally in combination with sulphur.
5. Silver can be beaten out into very thin sheets, and drawn out into very fine wire.
6. Silver dissolves in nitric acid, forming *silver nitrate.*

Lesson 43.—COPPER.

1. Copper is a red metal, and a good conductor of heat.
2. It is not hard, but may be hardened by the addition of small quantities of other metals.
3. The bronze used for coinage contains copper with a little tin and zinc.
4. Brass is a mixture of copper and zinc.
5. Copper is sometimes found pure, but most of it is obtained from minerals called malachite, cuprite, and copper pyrites.
6. It can be beaten into thin sheets and drawn out into fine wire.
7. It does not rust on exposure to air, but forms a black oxide when heated.
8. Nitric acid will dissolve copper.

Lesson 44.—GOLD.

1. Gold is very heavy, and can be beaten out till it is exceedingly thin. It can also be drawn out into very thin wire.
2. It is not at all hard, and does not rust, not even when heated.
3. It is found pure in nature, and is often obtained from the sands of rivers.

4. Mercury is often used to dissolve the gold out of the sand or crushed rock in which it is found.
5. Hydrochloric acid and nitric acid will not dissolve gold separately; but the metal is dissolved by *aqua regia*, which is a mixture of these two acids.
6. When gold is used in manufactures, it is hardened by the addition of a little copper.

Lesson 45.—IRON.

1. Iron is never used in a pure state, being rather soft.
2. Wrought iron, cast iron, and steel are three varieties of iron used in the manufactures.
3. Wrought iron is the purest and softest variety. It is tough, and can be rolled or beaten into sheets.
4. Cast iron is harder and brittle.
5. Steel is the hardest variety. It is brittle, like cast iron.
6. Iron combines with oxygen when exposed to damp air, forming rust.
7. It is obtained from clay ironstone and other minerals.
8. Clay ironstone is heated in a furnace with coal and lime. A slag is formed by the lime combining with the clay, and the melted iron sinks to the bottom.
9. Sulphuric, hydrochloric, and nitric acids all dissolve iron.
10. All three varieties of iron contain carbon.

Lesson 46.—TIN AND ZINC.

1. Zinc is largely used for covering the roofs of houses and for lining cisterns. It does not rust.
2. Galvanized iron is iron covered with a thin layer of zinc to protect it from rusting.
3. Zinc can be rolled into sheets.
4. It burns when heated, combining with oxygen.
5. It dissolves in hydrochloric, sulphuric, and nitric acids.
6. Tin is very soft, and melts easily.
7. It is largely used for covering iron, as it does not rust, and so protects the iron from the air.
8. Like other metals, tin is a good conductor of heat.

Part IV.—ORGANIC CHEMISTRY.

Lesson 47.—ANIMAL AND VEGETABLE SUBSTANCES—SUGAR.

1. All substances may be classified as follows:—

Inorganic, ...	Mineral.
Organic, ...	Animal. Vegetable.

2. All the known elements exist in the earth's crust, but organic compounds (known also as the carbon compounds) are built up of only a few elements, the chief of which are carbon, hydrogen, oxygen, and nitrogen.
3. When organic compounds are heated in a tube, a black mass is usually left behind. Sugar contains carbon, hydrogen, and oxygen.
4. Cold water will dissolve three times its own weight of sugar. Hot water will dissolve very much more.
5. Sugar-candy may be prepared by allowing hot syrup to cool.
6. Barley-sugar is prepared by melting sugar and causing it to cool rapidly.

Lesson 48.—MORE ABOUT SUGAR.

1. Sugar is to be found in the sap of most plants.
   Examples—Stem—Sugar-cane.
   Root—Beet-root and carrot.
   Fruit—Most ripe fruits.
2. Sugar is obtained from the sugar-cane by
   (a) pressing out the juice between rollers;
   (b) boiling the juice with lime to separate impurities;
   (c) boiling off the water till a thick syrup is produced, and then
   (d) allowing the sugar to crystallize by cooling.
3. The portion that does not crystallize is treacle or molasses.
4. White sugar is obtained by dissolving the brown sugar, filtering the solution through charcoal, and then recrystallizing.
5. Beet-sugar has the same composition as cane-sugar.
6. Grape-sugar is obtained from the juices of grapes and other fruits.
7. Grape-sugar may also be obtained from honey by washing it with spirit. The spirit dissolves away all but the grape-sugar, which is left as a sediment at the bottom.

8. Grape-sugar is not as sweet nor as soluble as cane-sugar.
9. Milk contains a kind of sugar called milk-sugar.

Lesson 49.—STARCH.

1. Starch contains carbon, hydrogen, and oxygen.
2. It is insoluble in cold water, but dissolves in hot water.
3. Starch is turned blue by iodine.
4. It may be obtained from a potato by rubbing, and from flour by well kneading in calico under water.
5. Starch exists in vegetables in the form of minute grains or cells.

Lesson 50.—A TALLOW CANDLE.

1. Candles are made of tallow and also of stearic acid.
2. Stearic acid is better than tallow for making candles, as it melts at a higher temperature.
3. Tallow contains carbon, hydrogen, and oxygen.
4. Oils and fats are insoluble in water, but will dissolve in ether, naphtha, and benzine.

Lesson 51.—SOAP.

1. Soap is prepared by boiling fat with caustic soda and water.
2. The soap is formed by the combination of the soda with the stearic acid of the tallow.
3. After the mixture has boiled for some time, salt is thrown into it. This causes the soap to float on the top, as it is insoluble in salt water.

Lesson 52.—SPIRIT.

1. Spirit or alcohol is a colourless liquid, with a strong odour and a burning taste.
2. It evaporates much more rapidly than water, and is therefore said to be a volatile liquid.
3. Spirit is lighter than water, and floats on it. But when the two liquids are shaken together, they mix, being soluble in each other.
4. Spirit boils at a lower temperature than water does.

5. Sugar will dissolve in water, but not in spirit; and certain gums will dissolve in spirit, but not in water.
6. Spirit is useful as a preservative. It is also used for making varnishes and polishes.

Lesson 53.—MORE ABOUT SPIRIT.

1. Spirit burns with a pale-blue flame, forming water vapour and carbonic acid gas.
2. Spirit is produced in certain vegetable substances by chemical changes which take place naturally.
3. When a mixture of water and spirit is boiled, the spirit evaporates at first much more rapidly than the water; and the vapour may be condensed by passing it into a cold vessel.
4. In this way alcohol may be obtained from ale or any liquid in which it is contained.
5. Spirits of wine is alcohol from which only part of the water has been removed.

Lesson 54.—VINEGAR.

1. Vinegar is formed when wine is exposed to air. The alcohol in the wine slowly changes into an acid.
2. The acid in vinegar is called acetic acid. It is colourless when pure, and turns litmus red. Purple cabbage is turned red by it when pickled.
3. White vinegar may be prepared by boiling ordinary vinegar and condensing the vapour given off. All the colouring matter remains behind.
4. When a vegetable blue colour has been turned red by vinegar, the blue colour can be restored by means of soda or any other alkaline substance.

EXPLANATIONS OF THE MORE DIFFICULT WORDS AND PHRASES.

1. *What is Chemistry?*

to be illustrated; to have its meaning made clear or plain.

2. *Elements and Compounds.*

had been much attracted; could not help looking at it and thinking about it.

is more advanced; when the subject is better known and better understood.

3. *Building up Compounds.*

briefly reminded them; repeated over to them again very shortly in order to recall to their memories.

atmosphere; the whole mass of air surrounding the earth; the air.

crucible; a melting-pot used by chemists, and able to stand very great heat without melting.

forge; a smithy; a place where iron or other metal is heated and then hammered into shape.

4. *Metals and Non-Metals.*

elementary substance; a substance that chemists have not yet been able to break up into simpler substances.

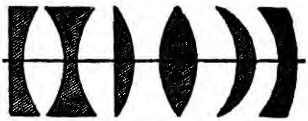
convert them into the liquid state; turn them into a fluid like water.

5. *Metals and Non-Metals.*

inquisitive; given to asking or seeking information about things in an annoying way.

6. *Mixtures and Compounds.*

lens; a transparent substance (usually glass) so formed that the rays of light passing through it are made to change their direction, and thus cause the object looked at through it to appear larger or smaller.



combine chemically; unite to form new substances.

7. *Matter cannot be Destroyed.*

misinformed; had been told what was not correct or true.

is perforated; has holes bored through it.

8. *Solution and Suspension.*

solution; the change of a substance from the state of a solid or gas to that of a liquid by means of a liquid called a solvent.

suspended; held up in the liquid, while still remaining solid.

impurities; matters that do not form chemically a part of the substance with which they are found.

decanting; pouring off a liquid so as to leave a sediment behind.

filtering; passing through a filter, so as to separate from the liquid the solid matter held suspended.

evaporation; driving off the liquid part by heat.

9. *Making Crystals.*

saturated; unable to dissolve more.

crystals; the name given to the regular forms which bodies usually take when they pass from the liquid to the solid state.

10. *Crystals Again.*

returning to the solid state; becoming a solid again.

11. *How to Analyse the Air.*

close the mouth of the jar; put in the stopper.

interrupted; stopped in the middle of what he was saying.

12. *About Nitrogen.*

concluded their remarks; finished what they had to say.

to detect them; to make sure of, or prove their presence.

13. *How to make Oxygen.*

mysterious; its purpose or use was not understood.

trough; a piece of apparatus by means of which gases can be collected in vessels. It consists of a vessel with a shelf an inch or two below the surface of the liquid. The shelf is perforated so that the vessel in which the gas is to be gathered can be placed immediately over the delivery tube. The gas displaces the liquid in the vessel which it fills.

14. *Experiments with Oxygen.*

suffocating; choking; stopping breathing.

15. *The Air is a Mixture, not a Compound.*

before they were really due; before the time fixed for their coming.

inactive; not entering readily into combination with other elements.

composition; the elements of which it is made up and the relative amount of each.

16. *Other Gases in the Atmosphere.*

are absolutely necessary for the support of life; there would be no life, as we know it, in the world without these.

volcanic districts; parts of the earth where heated material in some form is driven from the surface by internal forces.

17. *How Animals affect the Composition of the Air.*

absorbed; sucked up, or drawn in.

consisted; was composed or made up.

18. *How Plants affect the Composition of the Air.*

transferred; took from one place and put into another.

smouldering; burning slowly and without flame.

decomposing; splitting it up into its elements.

19. *The Composition of Pure Water.*

never varies; is always the same.

what a powerful attraction, &c.; how rapidly and vigorously they combined.

20. *Hydrogen.*

properties; peculiar qualities; those things by which it is known.

21. *Rain-water, Spring-water, and Sea-water.*

principal gases; chief gases; oxygen and nitrogen.

house supply; the water they used for drinking.

suitable for this purpose; fitted for getting fresh water from salt.

23. *Carbonic Acid Gas.*

funnel; a hollow cone with a pipe leading from the apex. It is used in putting liquids into vessels with small openings.

bubble; pass in the form of bubbles.

24. *Charcoal.*

combustible; able to burn in air.

25. *More about Charcoal.*

consumed; burned up; united to oxygen to form carbonic acid gas.

26. *Coal.*

changed vegetable matter; stuff that formed part of the bodies of plants, and has been turned into a mineral substance.

transparent; allows the light to pass through it.

cells; very small cavities or hollows in the structure of any substance.

chief element in coal; what coal is chiefly composed of; the greater part of the coal is carbon.

28. *Flame.*

disappointed; prevented from having what was wished or expected.

in contact with; touches closely.

deposit; matter that has settled down.

29. *Common Salt.*

distinguish from; mark the difference between.

museums; places where collections of objects connected with natural history, &c., are kept.

30. *Chlorine.*

irritation; a feeling of heat or pain.

31. *Bleaching.*

colouring substances; materials used for giving colour to other substances.

providing; on condition that.

recovered from their laughter; ceased to laugh.

32. *Acids.*

on former occasions; in previous lessons.

exchanged its hydrogen, &c.; gave up its hydrogen and took the metal instead.

thoroughly acquainted, &c.; knew perfectly what effect it would produce.

cautioned him; told him to take care.

33. *Oil of Vitriol.*

alcohol; spirit of wine.

34. *Alkalies.*

anxiously inquired; asked eagerly.

announce his subject; tell what the lesson was to be about.

35. *Washing Soda.*

water of crystallization; water held by certain salts as a part of their crystalline structure.

36. *Saltpetre.*

for further instruction; to be told what to do next.

37. *Sulphur.*

failure; being unable to do what he tried.

guide; help him to take the right way.

successfully employed; used in such a way as to get the result wished.

volcanic regions; tracts of land where there are or have been volcanoes.

condensing; changing from the state of gas or vapour into the liquid or solid state.

38. *More about Sulphur.*

different appearances; changes in its look.

plastic; that can be easily made to assume a new shape.

39. *Clay.*

used as a substitute for; takes the place of.

withstand; not be destroyed by.

porous; permitting liquids and gases to pass through it.

40. *Mercury.*

called the boys' attention to; told them to look at.

hissing noise; the kind of noise made when water touches red-hot iron.

41. *Lead.*

ore; a mineral consisting of a metal and some other substance in composition. Metals are got from the ores.

poisonous; causing pain or death if introduced into the body.

cements; materials used for joining bodies together.

42. *Silver.*

render it more durable; make it that it will wear or last longer.

conductor; a body that receives and carries along it heat, electricity, &c.

extract; to separate a metal from the impurities with which it is mixed.

43. *Copper.*

specimens; bits that may be taken as examples.

44. *Gold.*

for ornamental purposes; being made into rings, brooches, pins, &c.

coinage; the making of coins—sovereigns, shillings, &c.

45. *Iron.*

mystery; something hard to understand.

snapped; broke suddenly.

attraction for; enters readily into combination with.

46. *Tin and Zinc.*

preserve; keep from rusting.

47. *Animal and Vegetable Substances:—Sugar.*

vapours; the gaseous form a liquid or solid sometimes takes when heated.

48. *More about Sugar.*

stem; the stalk which supports the flowers or fruit of a plant.

molasses; the syrup that will not crystallize, which is formed in the process of making sugar.

49. *Starch.*

pestle; an instrument for grinding or breaking substances in a mortar.

50. *A Tallow Candle.*

generally employed; used by most people.

51. *Soap.*

alkali; a substance having properties like soda.

52. *Spirit.*

introduction; a statement made in bringing forward a subject.

volatile; passing rapidly from the liquid or solid state into the state of a gas.

varnishes; solutions of resin or gum used by painters, cabinet-makers, &c., to give a hard, clear. shining surface to their work, and to preserve and protect it.